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ISSUE 98

WELCOME

The magazine that feeds minds!

"If the universe continues to expand at a faster rate, all atoms and matter could be torn apart..."

The end of the universe, page 40

Meet the team...

Charlie
Production Editor
It's easy to think that our universe will always be around, but unfortunately it won't be. Find out how it might all end on page 40. But don't worry too much, it's still a few billion years away!

Jack
Senior Staff Writer
Being a big video game fan, it was a pleasure to get an insight into how the levels you play in are created and tested. Turn to page 68 to see how these virtual worlds are made.

James
Research Editor
Is nuclear fusion the answer to the world's energy problems? This issue, we've put together a piece on nuclear energy to explore this hot topic and the pursuit of clean fuel. Learn more on page 30!

Duncan
Senior Art Editor
Some say it's the fastest car ever made and produces more horsepower than the Grand National. Find out how the Bugatti Chiron is built for speed and style on page 12.

Laurie
Studio Designer
There's no denying that animals are incredibly clever – they've even mastered living in the mazes of our cities and towns! Flick over to page 22 to discover how these crafty urban animals have managed to do it.

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Most of us can only dream of being able to afford a supercar. One of the reasons for the hefty price tags on these vehicles is because automotive manufacturers invest huge amounts of money and time developing models that are faster, more powerful and more advanced than ever. Building a high-performance sports car requires precise engineering, high-tech materials and attention to each tiny detail to ensure every aspect works perfectly. This issue, we go behind the scenes to find out how it's done.

"It's not exactly *brain surgery* though, is it?", you might think, or "it's hardly *rocket science*...". These disciplines are often used as benchmarks for work that is incredibly complex, the pinnacle of intellectual ability. Our special feature this month pits the two ultimate scientific careers of brain surgery and rocket science head-to-head to find out exactly what it takes to succeed in these highly regarded and inspirational professions. Enjoy the issue!

Jackie

Jackie Snowden
Deputy Editor

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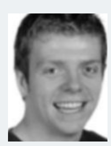
Meet the experts…

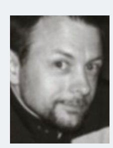
Mike Bedford
Mike has been a science and tech journalist for over 20 years, and is a senior research fellow at the University of Exeter. This month, he explores the latest innovations in materials science on page 58.

Laura Mears
Brain surgery and rocket science are often touted as some of the most difficult scientific professions. In our special feature, Laura pits them head-to-head to see who would win in this career clash.

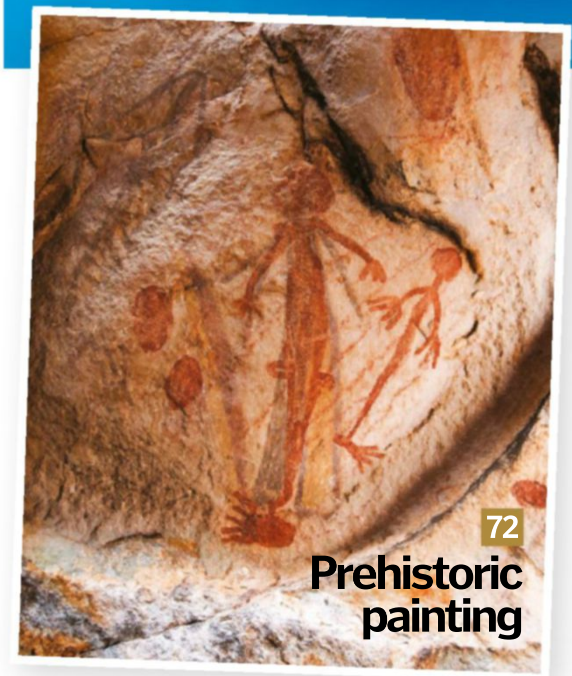
Ella Carter
Ever wondered why urban foxes are so successful, or why pigeons plague towns and cities? In this month's environment feature, Ella investigates which animals have adapted to life in the urban jungle.

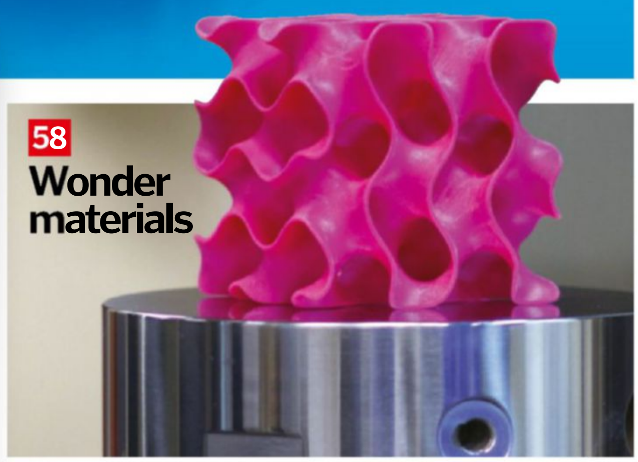


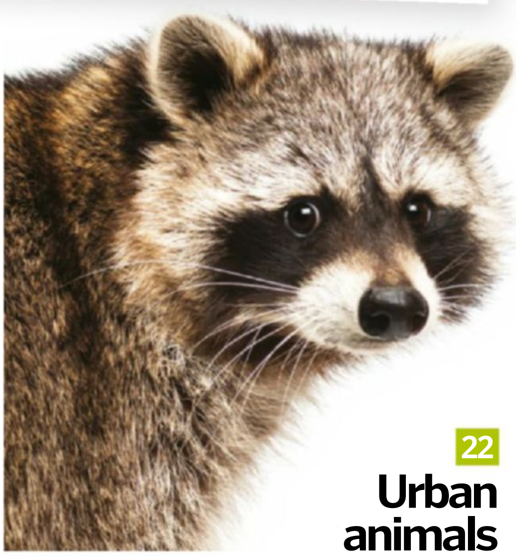
Jonny O'Callaghan
Are we headed for a Big Rip or a Big Crunch? Over on page 40, Jonny explores the various theories about the ultimate fate of our universe. He also explains how Mars' moon could form rings.



Mike Simpson
Mike goes behind the scenes to find out how supercars are designed, built and tested in our cover feature. Find out how engineers have constructed the Bugatti Chiron, the fastest road car in the world, over on page 12.







REGULARS

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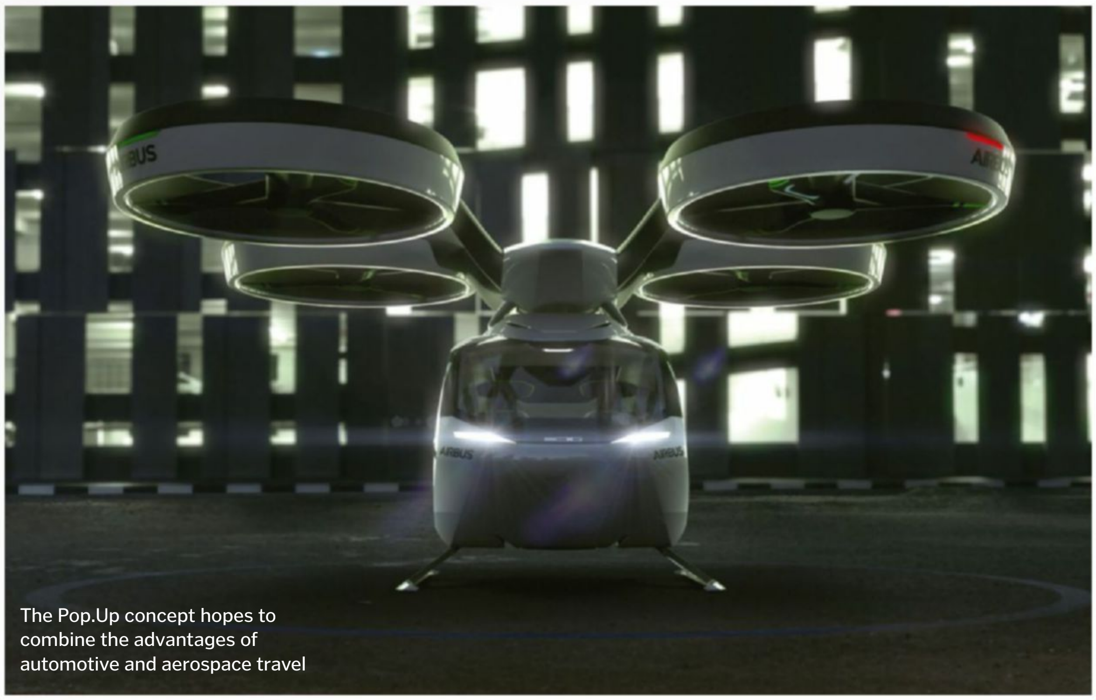
Airbus unveil drone-car hybrid concept

The aerospace giant has teamed up with design company Italdesign to rethink city transport

One of the most exciting presentations at the 2017 Geneva Motor Show was the Pop.Up, a modular air and ground passenger concept developed by engineers from Airbus and Italian design company Italdesign.

The idea behind the Pop.Up is to find a way of creating a sustainable urban transport system. Traffic is a major problem in cities. For example, in Los Angeles, the average person spends 104 hours a year in gridlock. By 2030, it is estimated that the cost of traffic congestion in the EU and the US will be around $350 billion (£280 billion).

The Pop.Up is a modular, fully electric, zero-emission concept designed to help tackle this problem. The vehicle system works by combining a passenger capsule with either the ground module (a car-like wheel base) or the air module (a drone-like roof attachment). Commuters can book their trip via an app, and an artificial intelligence system analyses traffic conditions to offer the best route, be it on the road or in the air.



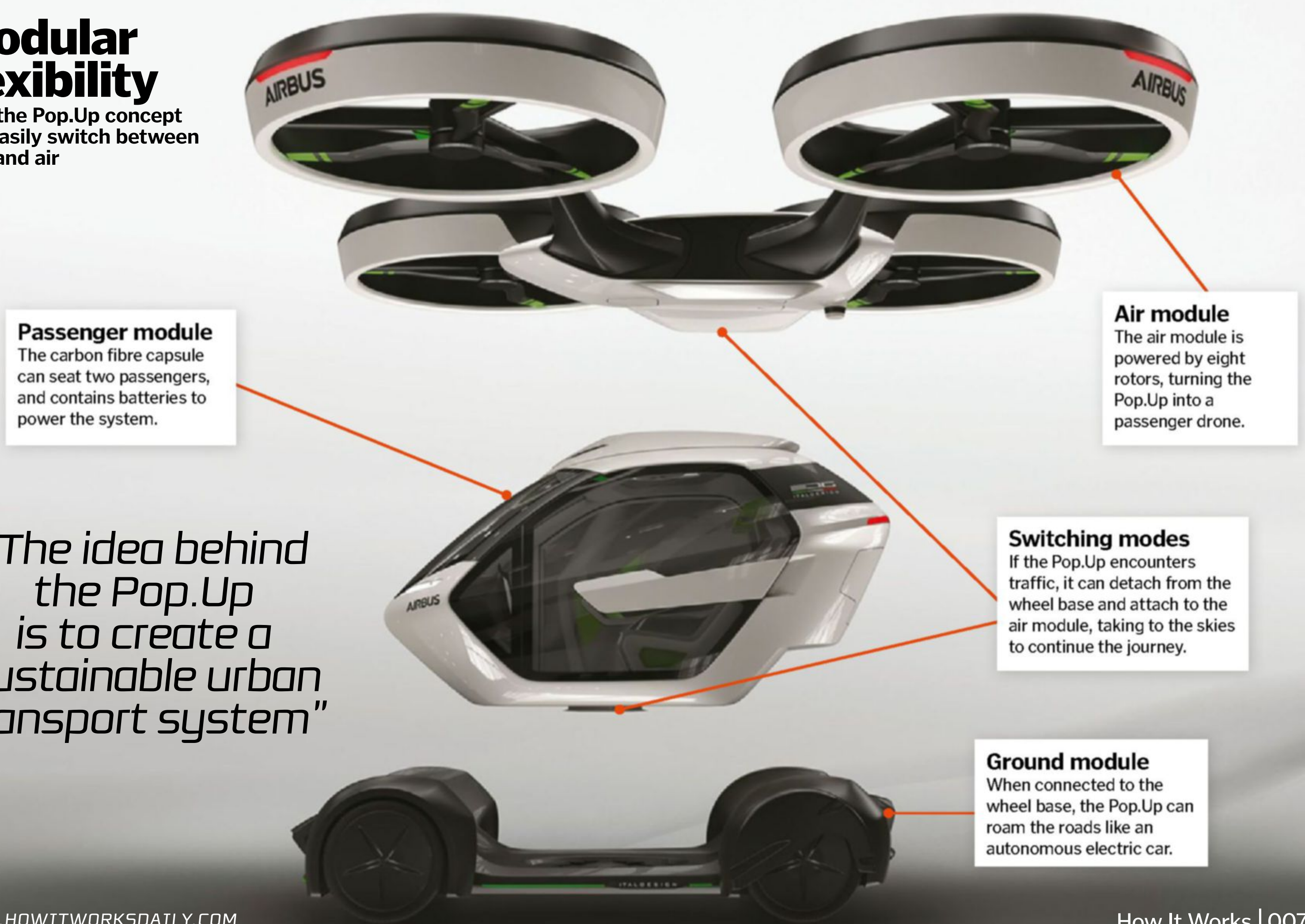
The Pop.Up concept hopes to combine the advantages of automotive and aerospace travel

The Pop.Up system can join on to the ground or air modules to offer passengers the most efficient journey

Commuters will be able to book their journeys via the Pop.Up's accompanying app

Modular flexibility

How the Pop.Up concept can easily switch between land and air



"The idea behind the Pop.Up is to create a sustainable urban transport system"

COULD PLUTO BE A PLANET AGAIN?

How a new classification system could reinstate the ninth planet, and add over 100 others

It's one of the most disputed topics in astronomy – is Pluto a planet or not? There have been calls to relabel this icy outpost on the far reaches of the Solar System as a planet after new data was reported at a recent international conference.

Pluto was initially thought to be a planet after its discovery in 1930, but in 2006 the International Astronomical Union changed the criteria of what defines a planet. By their new rules, a planet must be in orbit around a sun, have enough mass to assume a nearly round shape, and have cleared the neighbourhood around its orbit. Pluto fails the third criteria and so it was demoted to a dwarf planet. But Kirby Runyon, a member of the New Horizons team studying Pluto, has challenged this ruling.

"If you don't call a round world a 'planet' it just falls off people's mental radar. There is a psychological power to the word 'planet' that helps people realise it's an important place in space." Runyon has proposed a new classification that sorts planets into subcategories: moon planets (Titan), rocky planets (Earth), gas giants (Jupiter) and finally, icy planets like Pluto.

Some iconic figures in astrophysics are still against the inclusion of Pluto as a planet, though. Neil deGrasse Tyson responded to Runyon's proposal by arguing that Pluto couldn't be a planet as its orbit crosses Neptune's. Astronomer Mike Brown, who discovered parts of the Kuiper Belt, is in agreement, stating: "If you look at the Solar System with fresh eyes, it is really hard to not realise that there are eight big things dominating the Solar System and millions of tiny things flitting around."

Pluto is only one-fifth of the size of Earth and is smaller in mass than the dwarf planet Eris

New Horizons is part of NASA's New Frontiers programme, which aims to study the furthest reaches of the Solar System

The New Horizons Pluto mission

The New Horizons spacecraft is the first to purposely explore Pluto and has provided some of the best images of the dwarf planet. Launched on 19 January 2006, it has flown within 13,000 kilometres of Pluto, taking close-up imagery of its atmosphere and geology. The mission has shown Pluto to have many features that are present on the eight other planets within the Solar System. The surface has mountains and volcanoes of ice thousands of metres high that loom above frozen nitrogen and methane fields. Glaciers are also part of Pluto's terrain and temperatures can fall to -200 degrees Celsius. The images from the New Horizons suggest that Pluto has subterranean channels that could indicate heat coming from underground in the form of an ocean of slushy water ice. The New Horizons team also imaged Pluto's four moons: Nix, Hydria, Styx and Kerberos. The spacecraft is now set to head even deeper into space to explore the Kuiper Belt further.

NEWS BY NUMBERS

2030

The year China is aiming to put its Taikonauts on the Moon

56,000

The number of homes that will be powered by the world's largest floating wind farm

4.2%

The proportion of the UK's car market that is powered by alternative fuels

175

The amount of injuries caused annually in the US by April Fool's jokes

LHC finds five new subatomic particles

Could this discovery help explain the nuclear strong force?

CERN's Large Hadron Collider has discovered five new subatomic particles. The new finds are all different states of the Omega-c baryon, a type of particle that has three quarks. Quarks exist within neutrons and protons at the centre of atoms, and the discovery will help further our understanding of the strong force, which binds quarks together inside the atomic nucleus. It is one of the most significant finds since the Higgs boson in 2012. The particles were found during the 'beauty experiment', an operation to find information on what happened after the Big Bang.

The discovery will help shed light on the composition of atomic nuclei

The artificial island will include both a harbour and an airport

Artificial sea island to supply renewable energy

The new power hub will harvest wind and solar energy

An artificial island in the North Sea will provide renewable energy to northwest Europe. The North Sea Wind Power Hub will be situated around 150 kilometres off the coast of the UK, and solar panels and wind turbines will generate green electricity for 70 million people. The proposal will help power six European countries, and is designed to provide solar power in the summer months and wind power in the winter months.

Researchers from the university of Dundee have reconstructed the face of the man known as Context 958

Forensic techniques bring a medieval face back to life

A man who died over 700 years ago has had his face digitally reconstructed

The face of a 13th century man has been successfully reconstructed to show what he looked like. The 700-year-old skeleton was found in a medieval hospital graveyard underneath Cambridge University that was first excavated in 2010. Forensic techniques were used to carefully analyse his facial anatomy. The skeleton revealed that he had a strong physique and most likely worked as a labourer. He was aged between 40 and 70 and had a diet that consisted primarily of meat and fish.

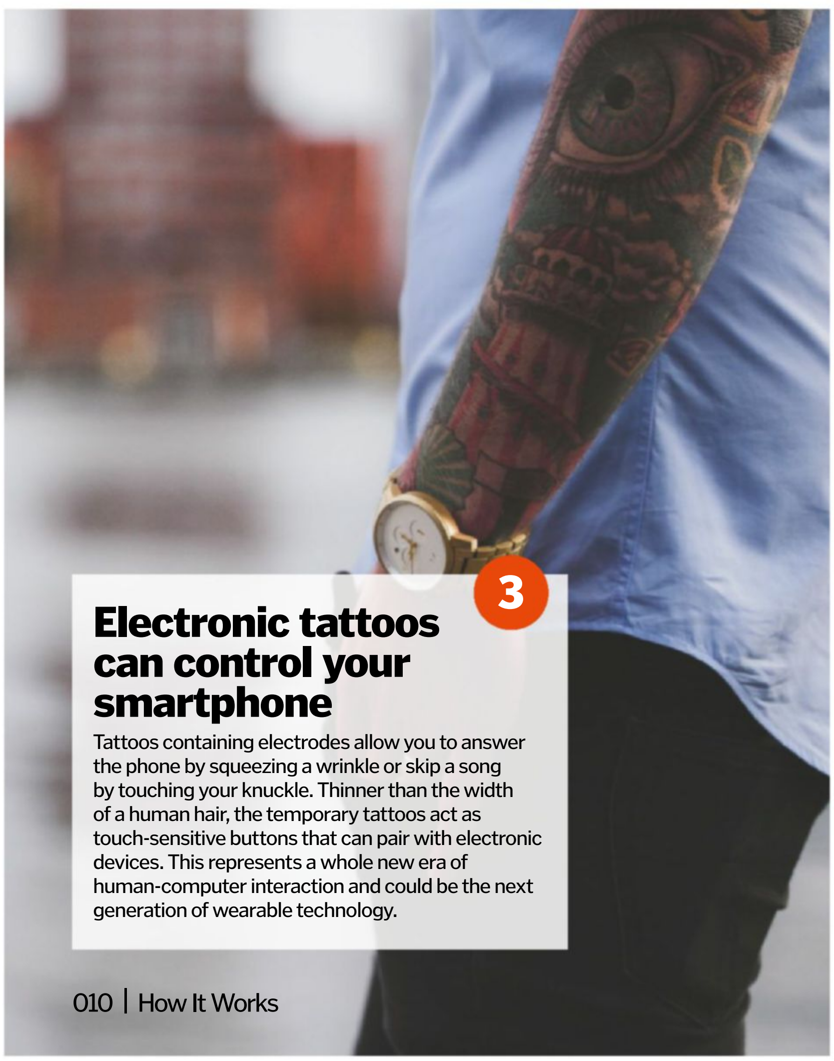
10 COOL THINGS WE LEARNED THIS MONTH

1 Drones can pollinate flowers

With bee populations in decline, researchers are considering the use of tiny drones to help artificially pollinate flowers. Working autonomously with built-in GPS and AI technology, the drones are covered in horsehair and gel and fly from flower to flower to collect and dispense pollen. A form of artificial cross-pollination, the idea has been successful in tests and is designed to complement rather than replace insects in a bid to increase global crop yields.

2 Sponges can help clean up oil spills

Environmentally damaging oil spills may be controlled in the future by a superabsorbent foam. Made from polyurethane or polyamide plastic, the material can absorb 90 times its own weight in oil using silane molecules to capture a spill. Sorbents, which are currently used, can only be used once, but the foam is simply squeezed out and reused like a sponge.

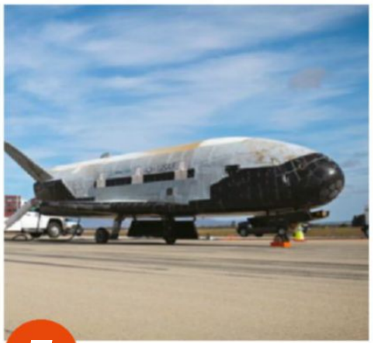


3 Electronic tattoos can control your smartphone

Tattoos containing electrodes allow you to answer the phone by squeezing a wrinkle or skip a song by touching your knuckle. Thinner than the width of a human hair, the temporary tattoos act as touch-sensitive buttons that can pair with electronic devices. This represents a whole new era of human-computer interaction and could be the next generation of wearable technology.

4 Urine could be used to grow food on Mars

For long-distance space missions, astronauts will be required to make their own food. Research by the German Space Agency has shown that bacteria in urine can help recreate the biological processes needed to grow food on Earth. Scientists grew tomatoes using bacteria from urine that turned ammonia into nitrates. The test will be undertaken next in simulated lunar and Martian gravity.



5 Boeing's space plane broke its own record

The experimental X-37B has recently beaten the flight duration records set by its own previous missions, having been in the air since May 2015. The official purpose of the mission is to explore reuseable spacecraft technology for future space missions. At the time of writing, the X-37B has been in flight for 672 days and counting, and will continue its orbit until its mission is complete.

6 You can 3D print with cheese

Cheese's ability to turn from solid to liquid and back again means it is an ideal candidate for using as an 'ink' in a 3D food printer. The dairy product was heated at 75 degrees Celsius and sent through a 3D printer in an effort to create edible 3D printed products.

7 Life on Earth began as drops of chemicals

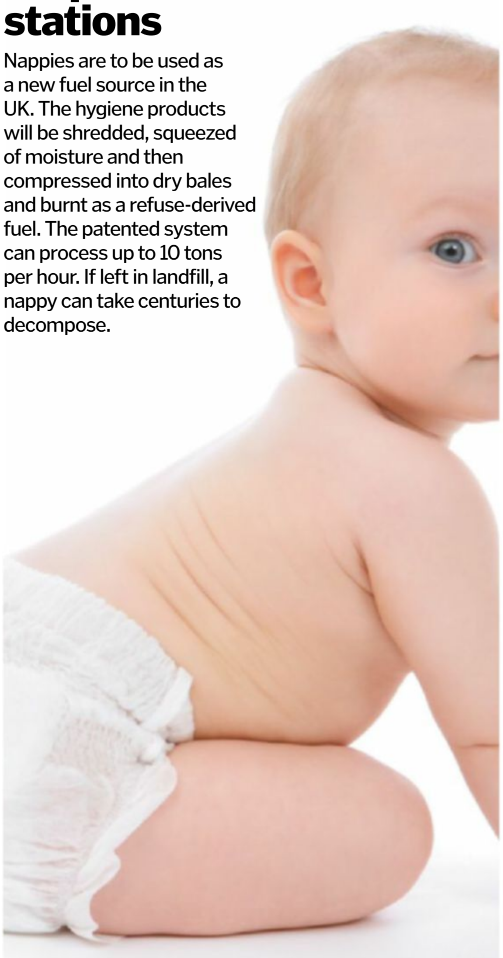
The first cells on Earth are believed to have derived from chemical droplets. Simulations have shown how the droplets successfully separated and replicated. The reactions could be the first instances of life, and gathered their energy from heat sources like hydrothermal vents.

8 Making mistakes pauses the brain

We all learn from our mistakes, but it takes more time than we might think. In a recent experiment, participants were asked a number of questions. When an incorrect answer was given, if another question was posed straight away, the chances of getting it right dropped by as much as ten per cent. This is known as error-induced blindness and demonstrates that the human brain's cognitive functions can be momentarily distracted by mistakes.

9 Nappies to fuel UK power stations

Nappies are to be used as a new fuel source in the UK. The hygiene products will be shredded, squeezed of moisture and then compressed into dry bales and burnt as a refuse-derived fuel. The patented system can process up to 10 tons per hour. If left in landfill, a nappy can take centuries to decompose.



10 Drinking tea could prevent Alzheimer's

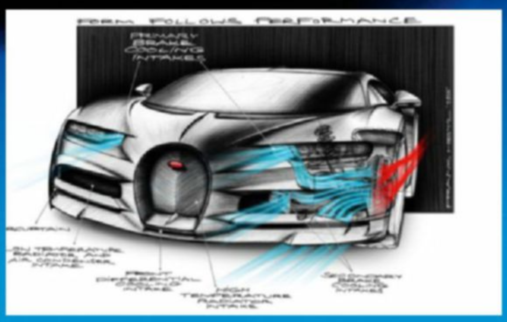
A new study has revealed that having a cuppa can help protect the brain from neurodegeneration. The results showed that regular tea drinking reduced the risk of cognitive decline in those over 55 years of age by 50 per cent. Black, green and oolong tea leaves contain bioactive compounds that have anti-inflammatory and antioxidant properties that may help prevent the onset of dementia from diseases like Alzheimer's.

HOW TO BUILD A SUPERC

DISCOVER HOW BUGATTI MADE THE CHIRON THE FASTEST PRODUCTION SPORTS CAR ON THE ROAD

Contrary to our fanciful artwork, no robots are used to build the Bugatti Chiron

The cabin design is constrained by having the gearbox in front of the engine



The design of the front includes several cooling air intakes while maintaining Bugatti's distinctive styling

What is a supercar? Ask automotive experts that question and they are all likely to give you a different answer. Take one look at the Bugatti Chiron, though, and you'll have absolutely no doubt that it deserves the distinction.

With a £2 million ($2.5 million) price tag, the Chiron conveys not only affluence but also an appreciation for exceptionally high standards. Alongside Bugatti, most well known manufacturers of racing cars, including Ferrari, Porsche, Lotus and Lamborghini, have produced road vehicles that are a cut above conventional sports cars. Yet none of these currently matches Bugatti as the foremost creator of high performance automobiles.

Bugatti has a long history of creating exceptional motor vehicles. The company was founded in 1909 by Italian-born Ettore Bugatti. He set up a factory in Molsheim, France, which was then under German control. After the Second World War the company experienced mixed fortunes for many years, including bankruptcy. The brand entered a new era in 1998, however, when it was bought by Volkswagen. The new owner immediately set about re-establishing Bugatti's reputation by starting a project to design and build the ultimate supercar – a vehicle that would push the boundaries of automotive luxury and engineering.

The result was the Bugatti Veyron. Entering production in 2005, the Veyron boasted 1,000 horsepower and could reach 400 kilometres per hour. The

The Chiron isn't just powerful – anodised aluminium trim adds class to its appearance

design combined unique styling with a host of mechanical innovations that were necessary for the car to reach and maintain its top speed safely. At the core of these was a unique 16-cylinder engine that earned Bugatti a world record in 2010 when a Super Sport edition of the Veyron reached a speed of 431 kilometres per hour.

The Veyron still holds the Guinness World Record as the fastest production car ever built. Even so, Bugatti hasn't rested on its laurels. The Chiron is a direct descendent of the Veyron, reflecting the belief among Bugatti's engineers that they could build a street-legal car that goes even faster.

CREATING A BIGGER BEAST

With the Veyron, the objective had been to design a car that could be driven at high speeds on the track and be equally at home on the high street. That ambition continued with the Chiron, but with the added criterion that its engine performance had to be 25 per cent better than the Veyron's. To achieve this, Bugatti's integrated team of designers and engineers went back to the drawing board, revamping the car from the inside out. Design concepts were rendered as 3D models in a computer and a full-scale clay version of the car was built to give the team a feel for what the finished product would look like.

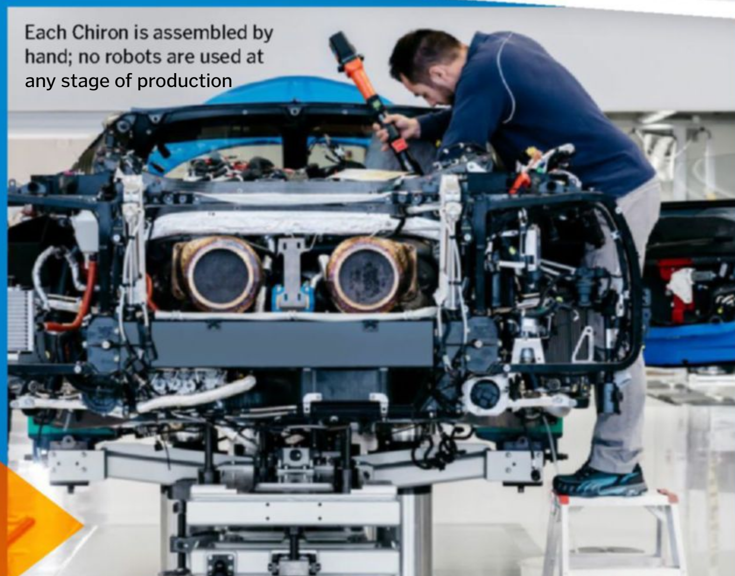
One thing Bugatti didn't reinvent, though, was the Veyron's incredible 8.0-litre W16 engine. Nonetheless, it has been updated in significant ways. The engine is assembled from handcrafted components made from strong but lightweight titanium alloys and carbon fiber. Over the period of about a week each engine is individually put together in a clean room to prevent grit from getting into the moving parts. The Chiron engine has 16 cylinders, like the Veyron's, but its four proprietary turbochargers are now double-powered. The specially designed clutch system, which has two transmissions, is also stronger than the Veyron's. This feature allows the Chiron to accelerate to its electronically-limited top speed of over 420 kilometres per hour

Inside the Atelier

Discover Bugatti's Molsheim workshop, a facility as amazing as the car that's built there

Ready and waiting
The front end of the transmission assembly is readied in position to connect to the drivetrain.

The EC nutrunner alerts the operator when each nut is at the required torque



Each Chiron is assembled by hand; no robots are used at any stage of production

Bare bones
Internal features are not fitted until well into the assembly process.

Shifting gears
The drivetrain must be aligned with a channel between the seats to connect to the gearbox.

Big moment
Connecting the frame of the driver's cabin, or monocoque, to the rear end is a milestone in the assembly process.

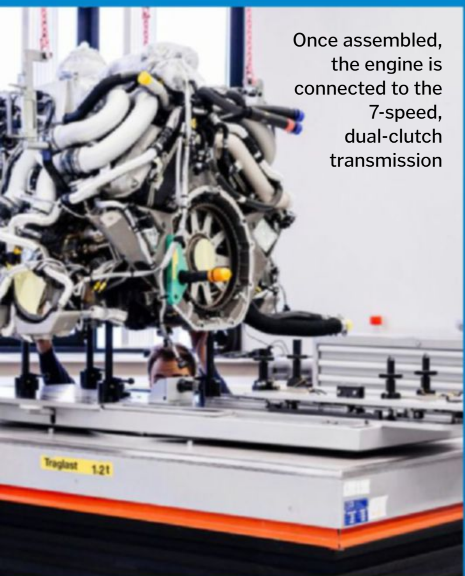
Team effort
The engine is so heavy it takes several engineers working together to push it into position.

Open spaces
Lots of space between stations allows parts to be moved without risking collisions with equipment.

Clean floor
The 1,000 square metres of floor space is made of epoxy that dissipates electrostatic charges.

> "'Form follows performance' is Bugatti's motto for this car"

Assembly stations are kept in pristine condition, with no oily rags in sight



Once assembled, the engine is connected to the 7-speed, dual-clutch transmission

The rear end of the car houses the massive engine and the powertrain

Veyron vs Chiron

The Bugatti Veyron is still an amazing vehicle, but expectations have risen in the decade since it went into production. Hence, Bugatti has surged ahead with the Chiron. This new car can produce 1,480 horsepower – almost half as much again as the original Veyron – and a higher top speed thanks to exploitation of physics and advances across the board in materials and mechanics. The most prominent sign of this is the Chiron's distinctive side air intakes, which keep down the temperature of the incredible engine by making air resistance work in the car's favour. Internal improvements, meanwhile, include staggered triggering of the more powerful turbochargers to boost engine efficiency, the use of lighter materials in the engine, frame and panels, and new disc brakes that are larger in diameter and thicker than the Veyron's. Together, these allow the Chiron to race past its record-setting predecessor.

Fierce competition pushed Bugatti's engineers to exceed their achievements with the Veyron

uninterrupted by gear changes. Essentially, when the driver shifts gears, the second transmission readies the next gear so that it engages as soon as it is needed.

To ensure the ambitious targets for the Chiron's engine wouldn't push it too hard, Bugatti's engineers tested the power output of a prototype using a dynamometer. The story goes that the engine survived but blew up the test apparatus, so a new dyno had to be specially built to complete the testing. Still, there is more to squeezing every ounce of performance out of a car than just boosting the output of its engine. Among the natural forces aligned against speed are gravity and wind resistance. To keep the Chiron ahead of the competition, Bugatti's designers have had to find new ways of exploiting the laws of physics to their advantage.

With a curb weight of almost two tons, the Chiron is heavier than the average car. To compensate for this, the frame and body panels, like the engine, are made from state-of-the-art materials that are light but strong. The former is assembled from high-strength steel with every joint bolted by hand. The only electronic tool used in assembling the chassis is an EC nutrunner. This high-tech spanner records how much each bolt has been tightened to ensure consistency and saves this data in a computer. The body panels, meanwhile, are comprised of carbon fibre strengthened by a honeycomb-structured aluminium inner layer.

Just as important as the physical properties of these panels, however, is the work that some of them do when they are on the car. Once attached to the frame, laminated and painted – a process that takes several weeks – they give the Chiron it's eye-catching appearance. 'Form follows performance' is Bugatti's motto for this car, and there is nothing that better exemplifies this than the Chiron's sweeping contours, especially the striking C-shaped motif that curves around the doors on each side.

A car with an optimal aerodynamic design deflects air without causing turbulence. To find the Chiron's ideal configuration, engineers studied a scale model in a wind tunnel so that they could map the air movement around different parts of its body. What this revealed is that the Chiron's front end could be designed in such a way that the air travelling up to and around the curved windscreen is channelled into more or less straight lines, called laminar flow. This minimises turbulence and directs airflows towards the back of the car where the engine is located.

One major problem the Bugatti team faced in designing an engine powerful enough to reach 6,700 revolutions per minute is that it would overheat quickly without an effective cooling system. The Veyron needed ten radiators to keep its engine temperature down, and the challenge was even greater with the Chiron. Therefore, the engineers came up with a water circulation system that can move up to 800 litres of water per minute through the engine.

Nevertheless, water-cooling is not enough, which is why those airflows deflected from the front of the car come in handy. The C-shaped panels that project out of each side of the Chiron are actually cleverly designed air intakes that collect deflected air and channel it into the engine compartment. This air acts like a fan, picking up the excess thermal energy from the engine before being sucked out of large vents in the back of the car due to a pressure differential.

CHALLENGING PHYSICS

The trouble is that airflows aren't all good for a supercar. When acting against an object going at high speed, air can lift it off the ground. You want that if you're jetting off on holiday in a plane, but for a car driver, even the slightest loss of contact with the road compromises vehicle handling and could be very dangerous.

To address this, Bugatti's designers have taken another lesson from the Veyron and given the Chiron a computer-controlled retractable spoiler. The purpose of the spoiler is two-fold – produce enough downforce to keep the car on the road when it's going fast, and slow it down safely if the driver needs to break when they have their foot to the floor.

At low speeds the spoiler remains embedded in the back of the car. As the car accelerates tiny sensors send signals to the onboard computer, which can trigger deployment of the spoiler in a fraction of a second. When the brakes are engaged, the spoiler adapts to help the driver complete their turn. This provides resistance to

How a rolling dynamometer works

The device that engineers use to see how much power a supercar can produce

Sensors
Sensor readouts can show how hot the engine gets and how much the car's structure distorts at intense speeds.

Data analysis
The dynamometer measures torque, which is how much force the engine must generate to turn the drum at a given speed.

Rolling drum
When the rear wheels rotate they turn a drum, and the rate at which it revolves is recorded by a computer.

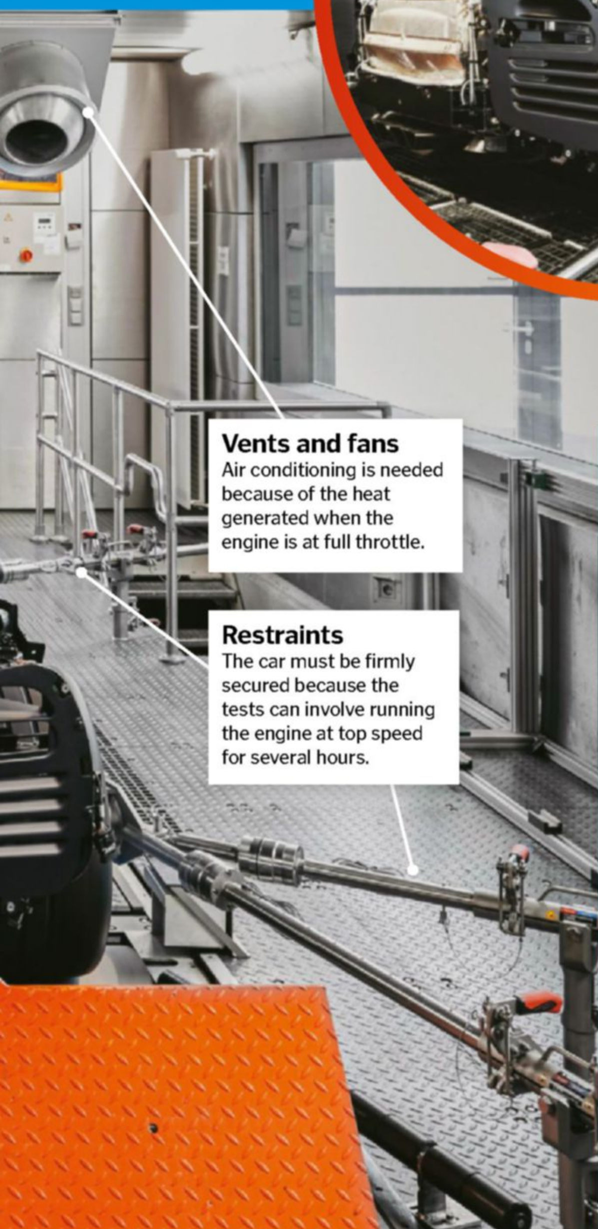

The car reaches maximum speed during a test-drive along an airport runway in Germany


Interior features made of leather or a leather-carbon fibre combination take days to fit


The rolling dynamometer is so powerful that excess electricity is fed to Molsheim's grid


Plastic foil coats the Chiron during its test-drive so the paintwork isn't chipped


The Chiron is drenched by monsoon-strength showers to check for leaks



Vents and fans
Air conditioning is needed because of the heat generated when the engine is at full throttle.

Restraints
The car must be firmly secured because the tests can involve running the engine at top speed for several hours.

"Engineers studied a scale model in a wind tunnel to map air flow around the car"


Every feature is extensively tested, including the car's rear-view camera

the oncoming air, which helps to slow the car down safely.

Also acting to bring the car to a stop are massive disc brakes made of carbon, ceramic and titanium. These discs are roasted in an oven at almost 1,000 degrees Celsius to ensure they won't fail in the most stressful conditions they could be exposed to. Here, also, the car's design enlists oncoming airflows to aid in heat regulation; a small duct behind each headlamp pushes air over the brakes to keep their temperature down.

But no matter how good the brakes are, the car isn't going to stop quickly enough if its tyres don't grip the road. That's why Bugatti asked Michelin to design a tyre unlike any the company had ever made before. Turning to aerospace technology for inspiration, Michelin created something that could survive the strain of braking under the enormous weight of an airliner. They also tested its traction on a course where any road condition the Chiron could face was simulated, even monsoon rains.

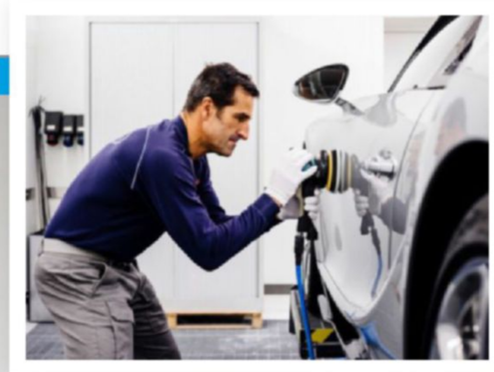
FINAL CHECKS

Back at the Bugatti factory, the Chiron's body also gets a good soaking. Once the paint has dried on the panels, the car is polished thoroughly before being inspected, then polished again. After that, it is moved to a special area where it is subjected to a fake rain storm. If no water is found inside, the luxurious interior is then fitted into the cabin by two people over a period of three days. Control buttons and knobs are made from anodised aluminium and optimally placed within easy reach of the driver. Owners are also offered numerous customisation options that include 23 different colours of leather, 31 colours of stitching and 11 different colours for the seatbelts.

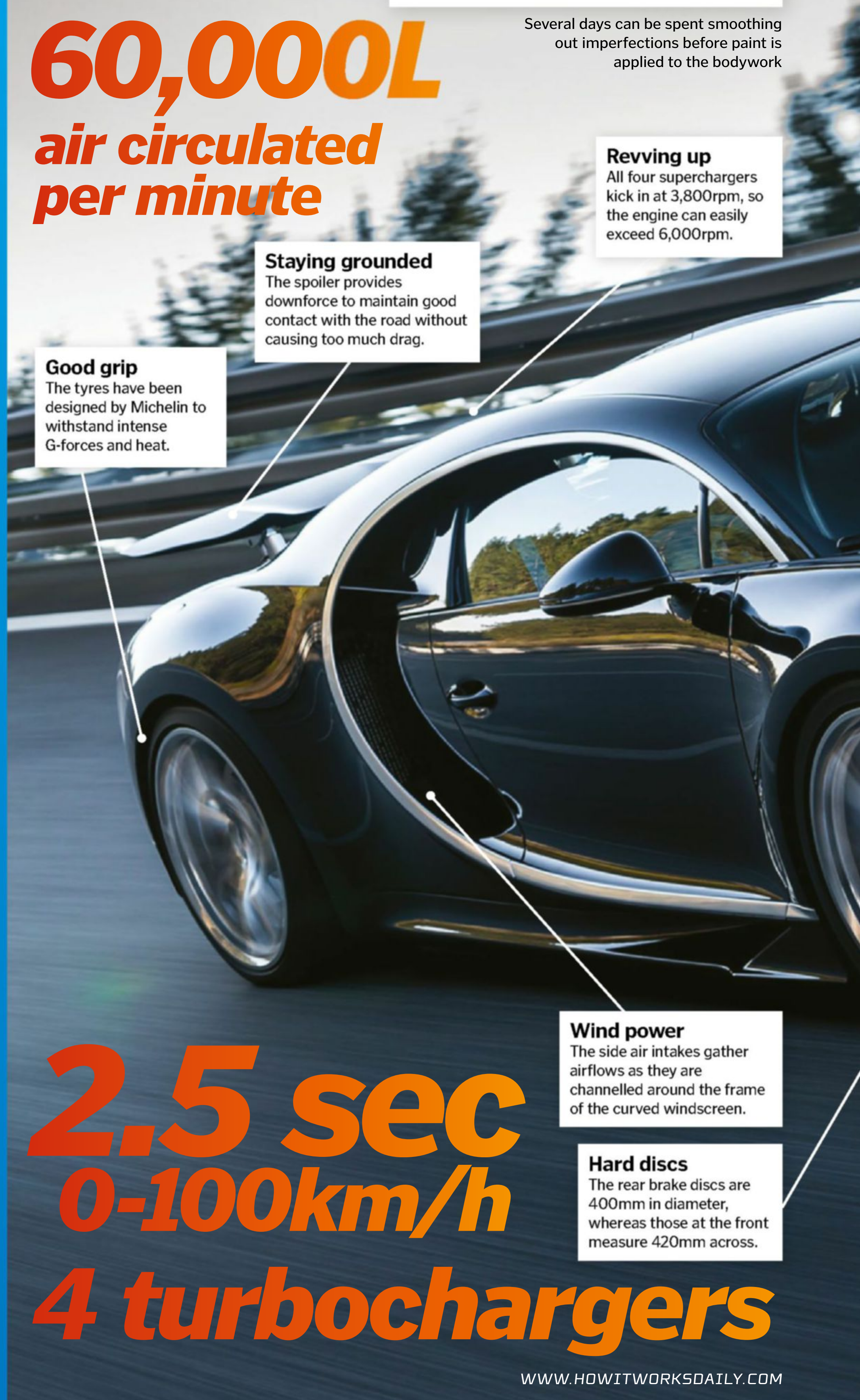
Bugatti is only going to make 500 Chirons. This guarantees that the car has an air of exclusivity. Moreover, it is an inevitable consequence of the six to nine months it takes to build just one car and put it through more than 300 kilometres of road tests. During the final outdoor workouts, the car is wrapped in transparent foil to prevent chips and scratches. With these tests completed, the car is taken to a light-room where it is inspected millimetre by millimetre. Only if it passes these final checks does it get Bugatti's stamp of approval. It's then released to its new owner, who drives away a sumptuous expression of speed and power.

Vital statistics

The big numbers that allow the Bugatti Chiron to leave other cars behind



Several days can be spent smoothing out imperfections before paint is applied to the bodywork



Another inspection for blemishes is done in the light tunnel

"Bugatti is only going to make 500 Chirons"

Total control
The driver can access all essential functions without having to take either hand off the steering wheel.

Cabin comforts
The interior is luxurious and efficient, with everything in easy reach and made from top grade leather or anodised aluminium.

Bright lights
Bugatti claims that the full-LED projector headlamps are the flattest ever fitted to a car.

Even gaps around the doors are checked to make sure they match Bugatti's strict specifications

16 cylinders

1,500hp

500hp more than the Veyron

Top speed

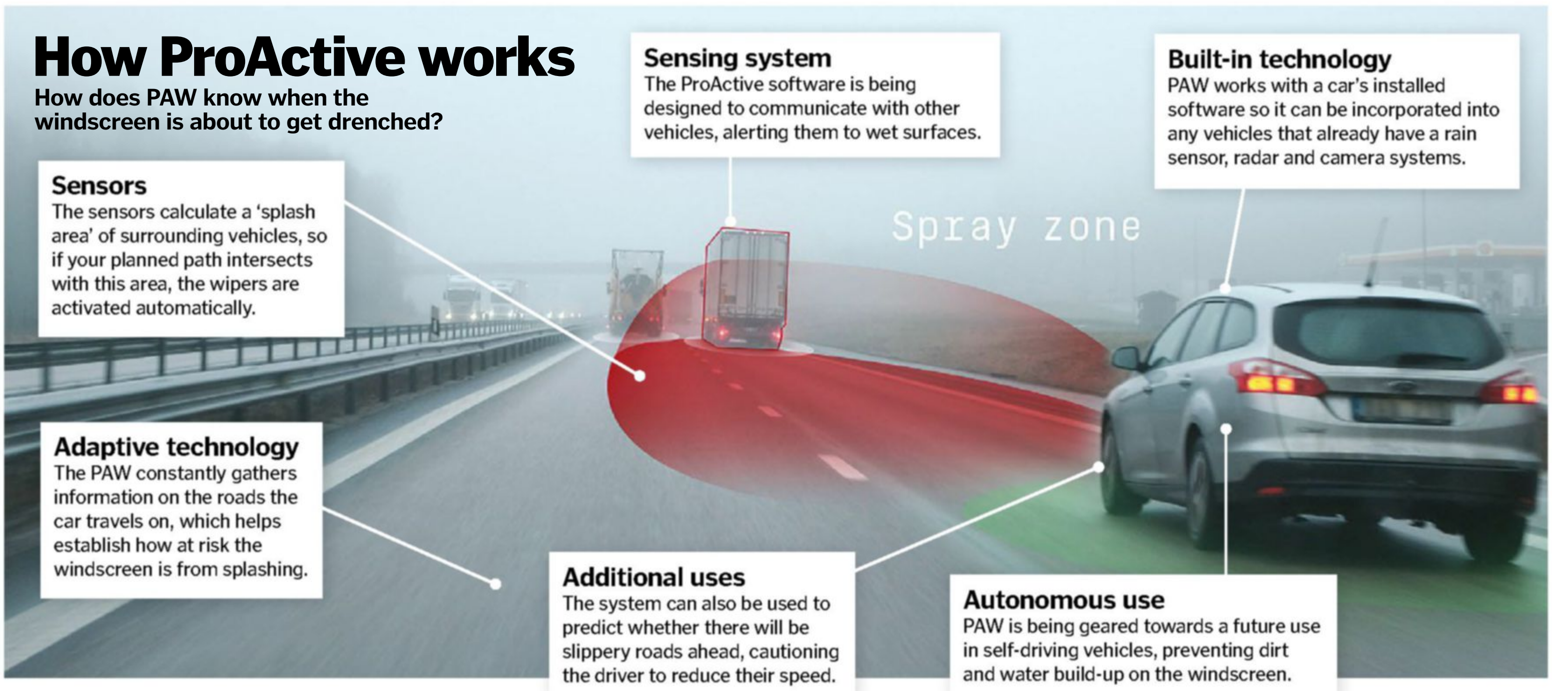
420km/h (limited)

ProActive wipers

A new system that can preempt when your windscreen is about to get wet

A recent survey has found that 50 per cent of drivers in the US feel nervous when overtaking a lorry in wet conditions. The main reason for this was the brief loss of sight experienced when a truck splashes up water from the road. ProActive wipers (PAW), invented by international technology company Semcon, could be a solution. A pre-activated wiper, PAW uses cameras, radar and rain sensors to accurately predict when spray from another vehicle will strike the windscreen. The software activates the wipers earlier than a standard rain sensor, so the spray is instantly wiped off with minimal loss of view.

Activated before the windscreen is drenched, PAW minimises the time the driver's view is impaired

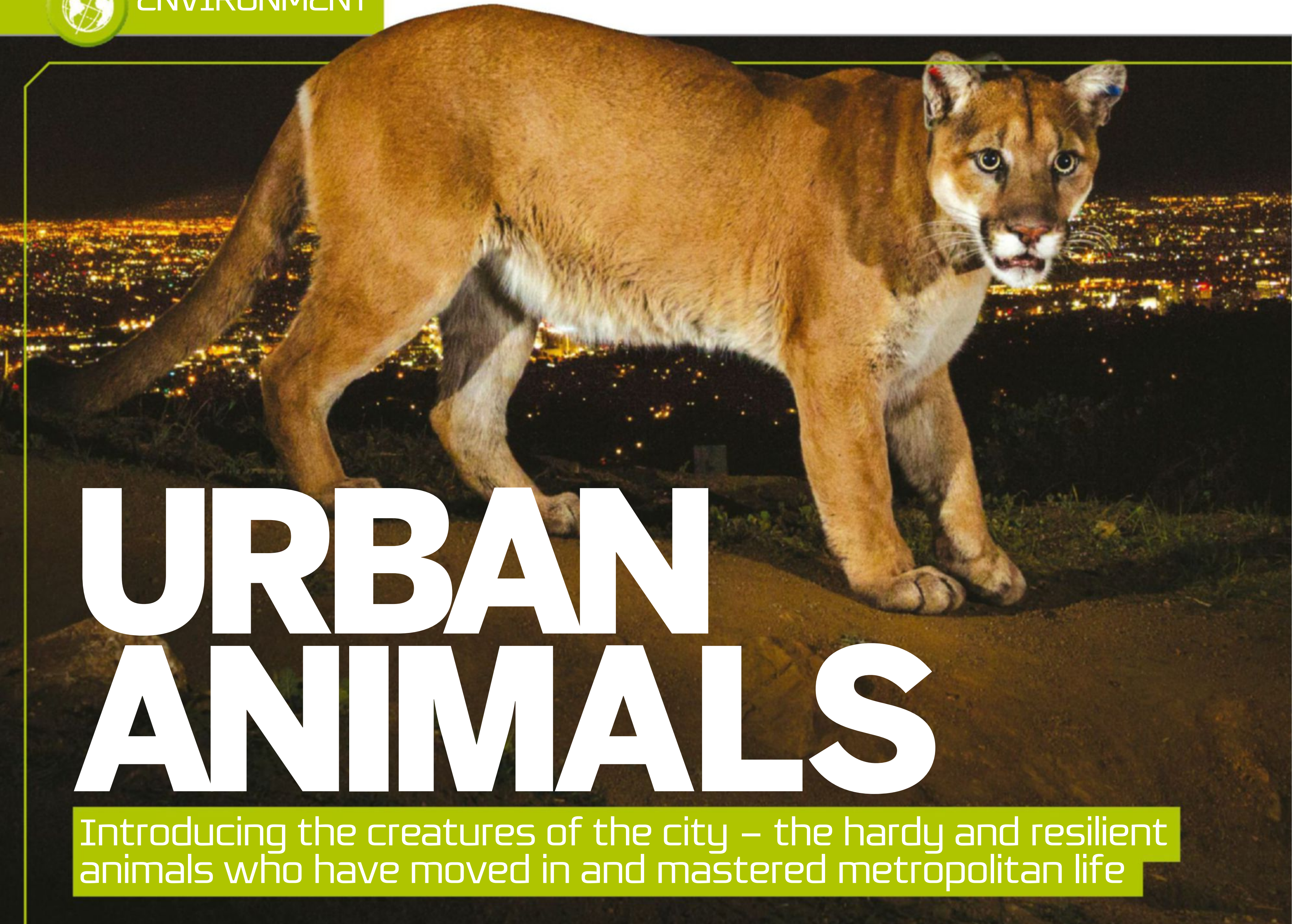


Aircraft catapults

Steam-powered propulsion systems that unleash jet fighters from aircraft carriers and into the sky


On land it can take 1,500 metres to get a fighter jet airborne, but with the steam catapult it takes only 100 metres

Military aircraft require a huge amount of power to lift off from warships. Underneath an aircraft carrier's deck are steam-powered catapults that help to give planes enough speed to get up into the air. Each catapult is composed of a pair of pistons inside parallel cylinders, which are designed to propel the aircraft using pressurised steam from the ship's reactors. The tops of the pistons are attached to the aircraft via a shuttle, and the aircraft is at first held in place by a strong bar known as a holdback. When the fighter jet is ready, the valves of the cylinders open and high-pressure steam floods into the mechanism. Because the pistons are still locked in place, they are unable to move and so pressure builds up inside them. When the pressure is sufficiently high, the aircraft blasts its engine to create considerable thrust. The holdbacks are then released and the catapult fires, providing the jet with a speed boost for launch. As the plane exits the carrier, the pistons crash into water brakes before being readied for the next launch.



URBAN ANIMALS

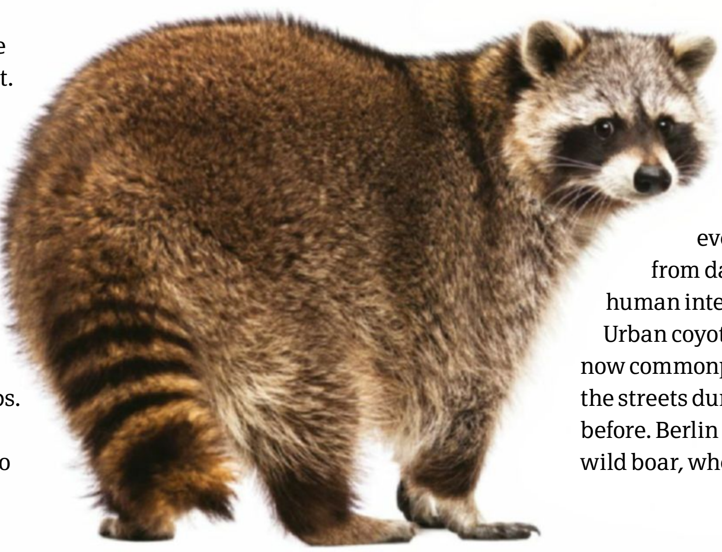
Introducing the creatures of the city – the hardy and resilient animals who have moved in and mastered metropolitan life

The world's cities are hubs of human activity and development, with over 3.5 billion people living in urban areas worldwide, and it's thought that this number will almost double by the year 2050. This influx of humans will be accompanied by the arrival of plenty more animal species. These clever creatures are able to adapt to ever-changing environments, grasp opportunities for survival and thrive on the fringes of our existence.

This is primarily down to the fact that where there are humans, there is food, and plenty of it. We produce so much that one study estimated that insects alone consume the equivalent of 60,000 hot dogs each year in one small area of New York City. Our cities are like an all-you-can-eat buffet for the animals living among us!

On the city streets, it's mostly the rubbish that we drop and discard that attracts animals such as rats and mice in their thousands, ready to feast on the plentiful scraps. In turn, these creatures attract much larger predators that will risk the hubbub of the city to feed on the booming populations of prey. In the UK, we are used to seeing animals like rats, mice and squirrels, and larger predators such as badgers, foxes and hawks. However, further afield, when sprawling cities blur the lines between human and animal settlement, even larger creatures venture onto the streets.

Native to North America, raccoons are often spotted rifling through rubbish bins for food



There are leopards that roam in between the high-rise flats of Mumbai, India, hunting domestic animals like cats and dogs as they are squeezed out of their natural habitat by urban development. Similarly, mountain lions and bobcats haunt the streets of Los Angeles as the growing city encroaches upon their natural range in the surrounding hills. Resourceful black bears in cities across the US are living on the edges of society, cruising dumpsters for tasty garbage having learned where they can find a quick and easy meal that requires less energy than hunting deer. Some have even adapted their foraging hours from day to night in order to avoid human interference.

Urban coyotes in cities such as Chicago are now commonplace, and can be seen prowling the streets during daylight more often than before. Berlin also has a thriving population of wild boar, where some 8,000 are estimated to

roam the city's parks and venture onto the streets, where food is available for snaffling and hunters are scarce.

Here in the UK, as well as plentiful food, the town dwellers are also offered numerous other perks. For example, there are plenty of places to hide – nooks, crannies and hidey-holes in buildings and beneath structures, and plenty of garden sheds to raise young. Thanks to our own building practises, these places are often insulated and warm – the perfect animal bolthole. As urban development expands further and further into the countryside, it's no surprise that animals will enter the city to find new places to live.

As generation after generation of animals live side-by-side with humans, they inevitably learn to adapt to city life. One of the most common creatures seen living in parks and tree-lined roads is the grey squirrel, which were introduced to UK shores from America in the late 1800s. City living is so appealing to these little tree dwellers thanks to the space and food available, and they are now much more common than our native red squirrels. They live high in the trees, can survive on a range of foodstuffs and, compared to the wild, there are relatively few predators in the centre of town.

In the wild, grey squirrels communicate with one another using various methods such as vocalisations, but some urban squirrels have been witnessed favouring only physical communication using their tails. It's entirely possible that these squirrels have adopted this to overcome the effect of noise pollution.

From an evolutionary standpoint, cities are incredibly new environments, and so the ability of these animals to move in, combat a new set of alien challenges and begin to thrive is amazing. However, it takes a certain type of critter to be able to do this, and studies have suggested that the animals making cities their homes are also becoming more intelligent. A US study of the skulls of small urban mammals from the past century has shown that the city dwellers experienced a jump in brain size when compared to their rural cousins, potentially indicating that living in an urban setting requires a higher cognitive function.

From a behavioural standpoint, the urban animals are certainly bolder than members of the same species living in the country. Many city species don't shy away or back down from human contact, and interestingly, scientists have also found that urban creatures are generally less aggressive.

Although many animals live on city streets, the homes that we live in within our urban settlements are also a haven for wildlife, although we may not even know or realise that they're there. There are of course the obvious culprits – mice, birds and bats can make their homes in the floors, ceilings and recesses of our homes and offices. Rats, however, are surely the animal conquerors of the human realm.

"As generations of animals live side-by-side with humans, they inevitably learn to adapt to city life"

Foxes are most common in residential areas with sizeable gardens, providing shelter and food scraps

Fantastic foxes

These small, rusty-red members of the canine family are a familiar sight in towns and cities across the UK. Arriving in urban areas in the 1930s and 40s, these animals are well-adapted to city life thanks to their unfussy attitude towards food. Opportunistic creatures by nature, foxes often choose the fast-food option of scavenging rubbish instead of hunting for prey, making city life appealing and easy.

Unfortunately, our urban foxes have a rather sour reputation thanks to their brazen attitude towards people (the only real difference between town and country foxes is that those living in towns tend not to be scared of humans) and their feeding habits, which can overlap with our livestock and gardens. Yet life for a fox about town isn't easy. The lifespan of these smart animals is roughly two years thanks to the dangers of road traffic and pest control measures.

The humble pigeon

These much-maligned birds are crafty city slickers that know what it takes to survive

Pigeons are a stalwart feature of city life. Found across the world in large flocks, pigeons (also known as rock doves) originate from the craggy cliffs of Europe and the Middle East. They have traded the rock faces of their ancestry for concrete skyscrapers and office blocks. The city has few natural predators, and roosting up high keeps them even further out of harm's way. Pigeons are scavengers and will peck at any scraps they can find, hence why they congregate in areas with plenty of human activity.

The pigeons we see in town centres today are all descended from escaped birds from dovecotes. These birds were once a main source of meat and an important method of communication, but modern technology has meant that our use for the humble pigeon has dwindled significantly.

Thought to be the most numerous mammals on the planet, rats have followed humans for thousands of years, feeding on our waste and benefitting from the spoils. It's estimated that there is at least one rat for every person in the world. These rodents are incredibly promiscuous creatures and a single pair can have over 1,000 descendants in a lifetime. Couple this with their ability to colonise areas like sewers (rats are powerful swimmers and can remember their way through whole systems of tunnels) and it's easy to see why they have been so successful at living in cities.

Insects are also very successful at forging a life in the city; there are more in cities than in the countryside. Scientists believe that this is to do with the temperature of urban environments compared to their rural counterparts. The vast expanses of buildings and roads made from substances like concrete and tarmac absorb, retain and slowly release heat. Where rural areas cool down after sunset, cities are veritable heat stores, creating something called the urban heat island effect. A warmer environment in the middle of cooler countryside attracts insects, and this is especially prevalent in the UK, which is the northern limit for many species. Cities are also known for their lack of relative overall biodiversity, so for incoming insects the limited competition from other species for space and resources allows more populations to flourish.

Although an influx of insects may sound like a bad thing to us, these small animals can benefit our towns in interesting ways. Insects and other arthropods work to clear our streets of organic matter, be that dropped junk food, rotting leaves that pile up in the autumn or roadkill on busy thoroughfares. Without the hundreds of thousands of tiny creatures patrolling our streets, the city would be an even dirtier place.

From insects crawling in the very foundations of our towns and cities to up high into the airspace above the tallest skyscraper, birds are also joining the metropolitan migration. Pigeons are probably the most recognisable when it comes to city birds, closely followed by seagulls. Smaller birds such as tits and finches are also incredibly successful city residents, and this is due to their diet. There are higher densities of people in cities that may put out bird feed to attract feathered friends. And of course, where the prey animals are, the predators soon follow. There are more peregrine falcons living in London than ever before, using their incredible hunting skills to swoop down and snatch pigeons in mid-air. These birds of prey are being encouraged – and even deployed – by falconers to keep the smaller bird populations under control. This is yet another way that wildlife can benefit our urban settlements.

The cities provide more resources thanks to our edible hand-me-downs and much lower risk of predation, which makes the city a very attractive place to live if you're a small prey animal or a keen, opportunistic forager. For the predators, there's less competition for food and a whole host of prey to choose from, and when that fails there'll always be a dustbin open for business somewhere. Even though the urban environment has never been intended for animal life, the natural world is encroaching onto our streets at a surprising speed. However, when wildlife and humans are living cheek-by-jowl this often results in conflict. Many animals simply aren't welcome in towns and cities, and there are also a whole load of dangers thanks to traffic, pest control and the lure of eating garbage. The next time you see a pigeon strutting on the tarmac or glimpse the tail of a rat disappearing into a crack in the pavement, remember that you're witnessing a whole new kind of colonisation, and that the animals are all around you, thriving off the things that you create and leave behind.

Trotting through town
Berlin is known for its wild boars, which occasionally attack locals if disturbed.

Learned behaviour
As more generations of animals are born and raised in cities, these tricks are passed to their young, creating a whole new set of behavioural adaptations.

Rubbish foraging
An iron stomach and a determined attitude drive raccoons to invent novel ways of getting at garbage in bins.

The animal underworld
With a network of tunnels, running water, little human interference and plenty of food, the sewers are the small animal superhighways of the city.

Life on the streets

How urban wildlife has adapted to thrive surrounded by our buildings, roads, pavements and sewers

Pigeon roost
Once a key source of meat and essential communication, pigeons now make their homes roosting on high-rises.

Changing behaviours
Thanks to light pollution, some insects, like moths, have adapted to resist the lure of lights.

Light pollution
The amount of artificial light generated by cities also attracts insects, like bright floodlights used to illuminate outdoor areas.

"It's estimated that there is at least one rat for every person in the world"

Clever coyotes

Once thought to actively avoid human settlements, these shy canines have now slipped into cities across America and are enjoying the food and shelter afforded by urban living. A major appeal is the lack of wolves or mountain lions, predators that threaten their survival.

In the wild, coyotes hunt by day, but city coyotes have been witnessed changing their foraging times in order to avoid human contact. As amazingly adaptable animals, critter cams tracking these wild dogs have captured the coyotes stopping to observe traffic before crossing roads and railways.

The coyotes manage to maintain home territories in the city, and one individual even raised a healthy litter of cubs in a den in the parking lot of Soldier Field Stadium, home of the Chicago Bears American football team.

Once only found in the middle of America, coyotes now live in almost all major US cities

Rat success
Living alongside humans for thousands of years, rats are perfectly poised to exploit our waste products, helping their populations flourish.

Paris is set to spend €1.5 million clearing the city of rats

Squirrel life
Strong climbing legs and an adaptable diet are key attributes for the grey squirrels that make the most of city life.

Why rivers meander

Find out what factors cause rivers to curve

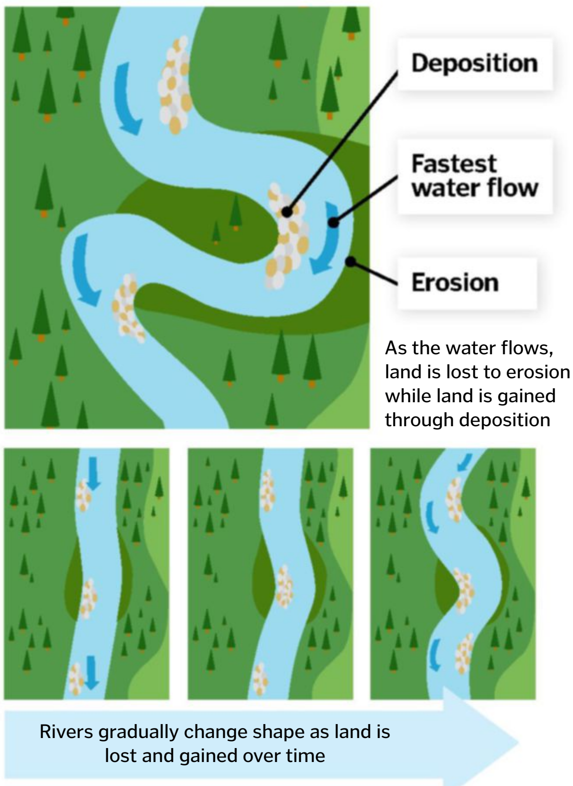
The winding curve or bend in a river is the result of erosional and depositional processes. River water flows around various obstructions, such as stones and rocks, which results in different areas of slow- and fast-moving water.

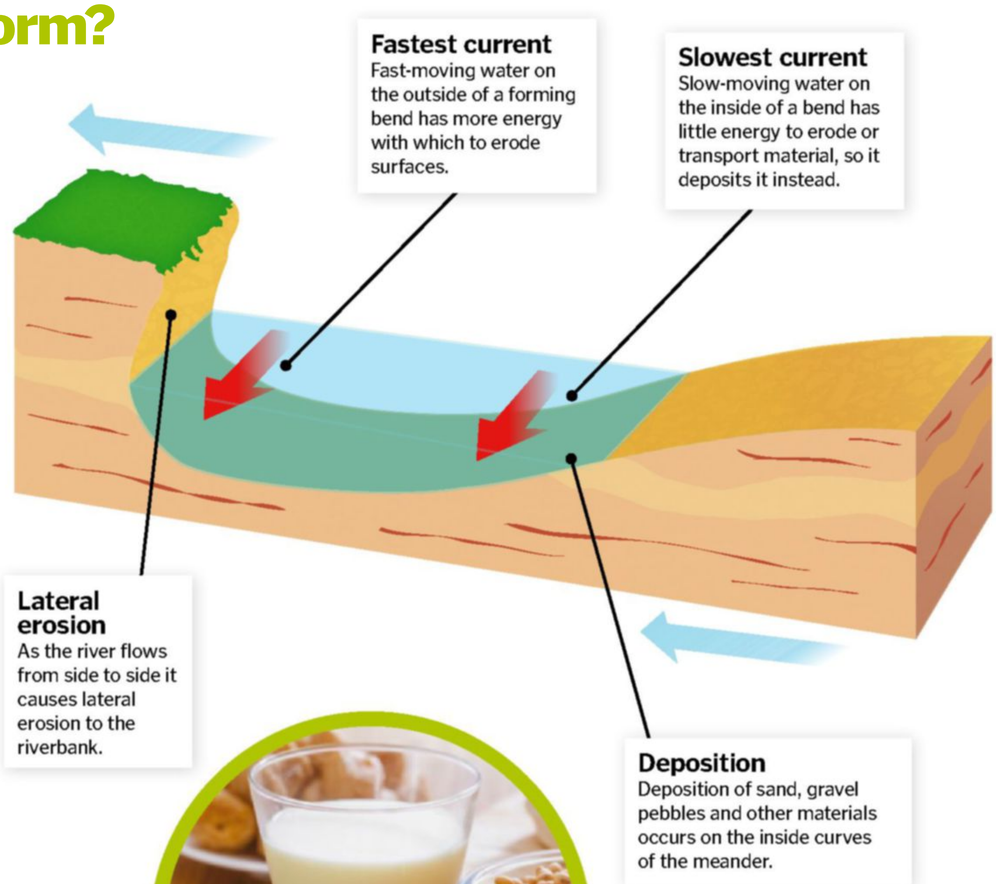
Deeper parts of the river contain slower areas of water and are filled with fine sediments. These parts are known as pools. Shallower parts of the river contain faster areas of water and larger stones. These areas are called riffles. The river flow swings from side to side and, over time, the pools move to opposite sides of the relatively straight channel.

As fast-flowing water erodes the outside of the pool and slow-flowing water deposits various materials on the inside of the pool, meanders begin to occur.

How does a meander form?

Take a look at the processes that create a winding river





Soybean plants

Discover what makes this ancient crop such a versatile plant all over the globe

The soybean plant is an erect branching plant that can grow to more than two metres high. It thrives in warm, fertile, well-drained sandy loam. The flowers are self-fertilising, white or purple in colour, and there are up to four seeds per pod, which are mostly brown in colour.

The soybean is an annual legume of the pea family. As one of the richest and cheapest sources of protein, it provides vegetable protein and ingredients for hundreds of chemical products, making it economically the most important bean in the world.

Commonly consumed as soy milk and tofu, the beans can also be eaten as a vegetable in salads and other meals, or crushed and fermented to produce soy sauce and miso. The oil from a soybean can be processed into margarine, shortening and vegetarian cheeses, and even used industrially in paints, adhesives and more.

Botanists generally claim that the soybean plant was domesticated around 7,000 BCE in China. However, although it's been used in the east as a food and a medicine component for thousands of years, the west has only been aware of its nutritional value for the last 250 years.

The soybean plant can be cultivated in most types of soil

Anatomy of a giraffe

Discover how one of the world's most iconic animals has adapted to its environment

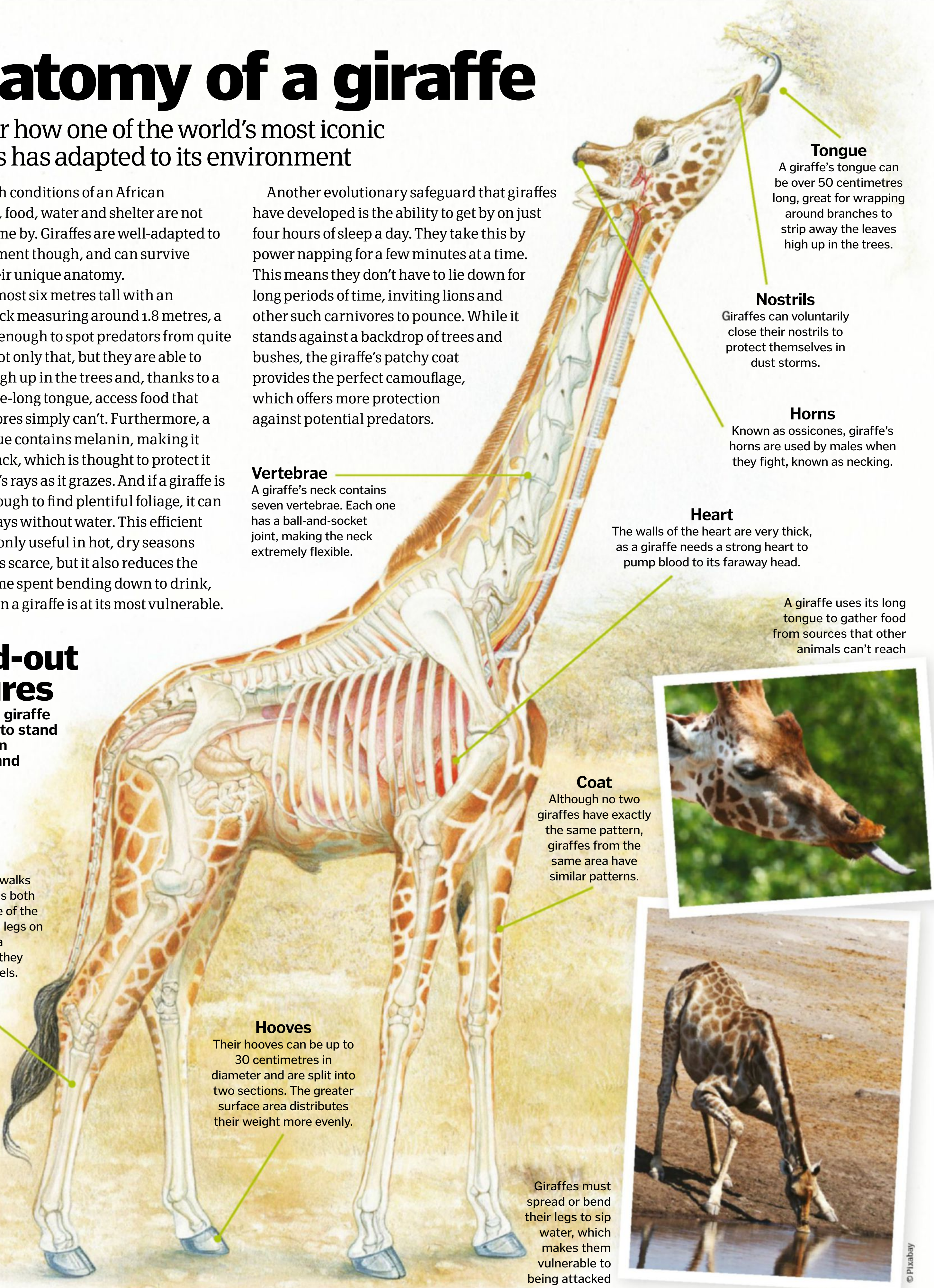
In the harsh conditions of an African savannah, food, water and shelter are not easy to come by. Giraffes are well-adapted to this environment though, and can survive thanks to their unique anatomy.

At up to almost six metres tall with an elongated neck measuring around 1.8 metres, a giraffe is tall enough to spot predators from quite a distance. Not only that, but they are able to reach food high up in the trees and, thanks to a 50-centimetre-long tongue, access food that other herbivores simply can't. Furthermore, a giraffes tongue contains melanin, making it dark blue-black, which is thought to protect it from the Sun's rays as it grazes. And if a giraffe is fortunate enough to find plentiful foliage, it can survive for days without water. This efficient eating is not only useful in hot, dry seasons when water is scarce, but it also reduces the amount of time spent bending down to drink, which is when a giraffe is at its most vulnerable.

Another evolutionary safeguard that giraffes have developed is the ability to get by on just four hours of sleep a day. They take this by power napping for a few minutes at a time. This means they don't have to lie down for long periods of time, inviting lions and other such carnivores to pounce. While it stands against a backdrop of trees and bushes, the giraffe's patchy coat provides the perfect camouflage, which offers more protection against potential predators.

Stand-out features

See how the giraffe has evolved to stand tall in African woodlands and savannahs



A giraffe uses its long tongue to gather food from sources that other animals can't reach

Giraffes must spread or bend their legs to sip water, which makes them vulnerable to being attacked

© Pixabay

The Skeleton Coast

Discover why so many shipwrecks can be found on the coast of Namibia

Along the northern stretch of the Namibian coastline in western Africa, the desert sands are littered with the remains of ships and the bones of their ill-fated crew. The reason so many have met their fate on these shores is because of the region's unusual climatic conditions.

The warm, dry air of the Namib Desert colliding with the cold water of the Atlantic's Benguela Current creates a dense fog over the sea. The poor visibility combined with the strong force of the current and winds have made it difficult for ships to navigate safely along the treacherous coast, causing many to run aground. The crew members that managed to survive the initial wrecks were then faced with crossing the seemingly never-ending desolate desert wilderness in search of food and water.

Many sadly perished in the sweltering heat, but it's not solely their remains that earned the Skeleton Coast its name. That came from the vast number of animal carcasses that washed up on the shore as a result of the whaling operations and seal hunting that were once common in the area. The harsh desert conditions have meant that the bones haven't decomposed, and so can still be found alongside the human skeletons.

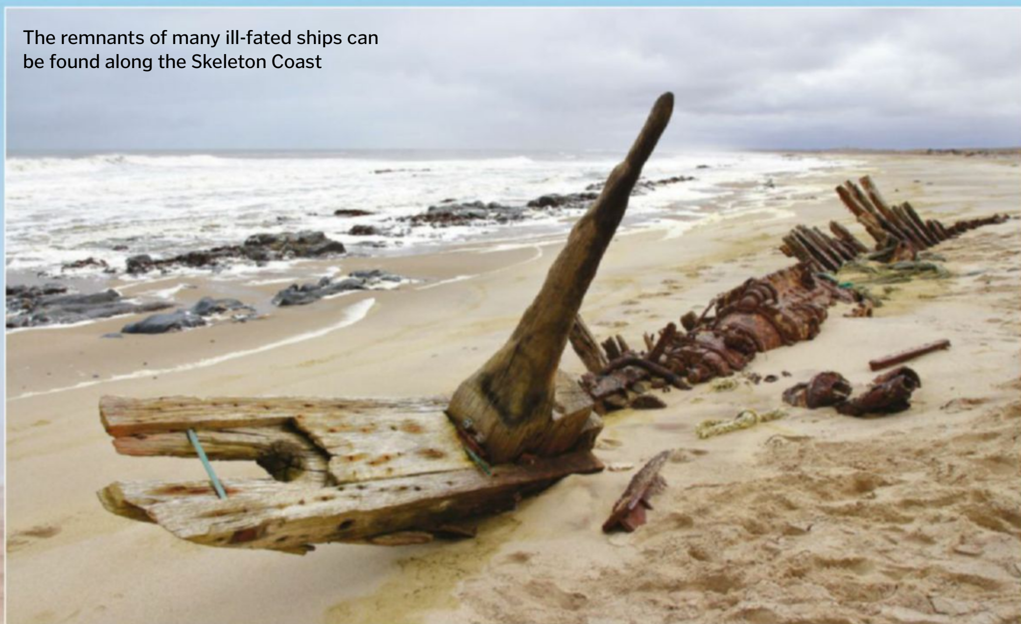
Shipwrecked in the desert

One of the Skeleton Coast's most famous shipwrecks can be found far from the ocean

Tragedy strikes
The Eduard Bohlen was a German cargo ship that ran aground on the Skeleton Coast in 1909.

Shifting coastline
Over time, the desert has slowly encroached on the ocean, moving the shoreline westwards.

Elephants migrate along the desert's river channels in search of food and water


The remnants of many ill-fated ships can be found along the Skeleton Coast

Wildlife of the Skelton Coast

It may be inhospitable for humans, but the Skeleton Coast is home to a variety of animals that have adapted to the extreme conditions. Elephants, rhinos, lions, giraffes and springboks can all be found roaming the four main dry riverbeds that snake towards the coast, while jackals and hyenas scavenge for dead birds, fish and seals along the shore.

The latter belong to a colony of around 120,000 cape fur seals that take advantage of an Atlantic buffet created by the strong Benguela Current. As ice-cold water is forced up from the depths of the ocean, it dredges up masses of food for fish, which in turn provide a meal for the seals.


Warm-blooded cape fur seals can regulate their body temperature in the cold Benguela Current

"The harsh desert conditions have meant that the bones haven't decomposed"

NUCLEAR POWER

Investigate how today's nuclear power stations work and delve into the promise of nuclear fusion

The idea of harnessing energy from nuclear reactions to generate electricity is over 60 years old. Following a slow-down in the 1970s, nuclear power is now on the rise again, partially in response to concerns over the harmful effects of burning fossil fuels. Today's commercial nuclear reactors generate energy from the process of nuclear fission, and we'll investigate what that means, why it generates so much energy and how a nuclear power station works. However, while fission is a tried and proven technology, many scientists believe that the future is one of nuclear fusion. Over the next few pages, we'll take a look at that process to see how it differs from fission and how far we are from generating power from this potentially abundant energy source.

Chemical bonds contain a large amount of energy, which can be released by chemical reactions. Burning fossil fuels is a classic example, and the amount of energy that can be produced this way is evident if we think about how far a car can travel when a gallon of petrol is oxidised. But the amount of energy stored in chemical bonds is tiny compared to the amount of energy that is stored in the bonds between the protons and neutrons in the nucleus of an atom.

It is this energy that is released in the nuclear reactions that take place in nuclear power plants, and the benefit compared to burning fossil fuels is staggering. Weight for weight, fission of nuclear fuel can produce 2-3 million times more energy than burning coal or oil.

Scientists first recognised the potential of nuclear energy in the 1930s and, while he was by no means the only researcher of note, Italian physicist Enrico Fermi has been acknowledged as the 'architect of the nuclear age'. In 1939, Fermi took up a position at Columbia University in the US, where he detected the release of energy from nuclear fission and, by 1942, had helped to build the world's first self-sustaining controlled nuclear chain reaction. However, political events were soon to alter the course of research into nuclear technology. With America involved in World War 2, Fermi was enlisted into the Manhattan Project where, together with other eminent scientists, most notably Robert Oppenheimer, he would be instrumental in the development of the nuclear bomb.

Following the end of hostilities, attention returned to nuclear fission as an energy source for peaceful applications. The first commercial nuclear power station, Calder Hall in the UK, opened in 1956, generating 50 megawatts. Within just a few years, nuclear power plants were also operating in the US, Canada, France and the USSR. Today, there are about 450 operational stations in 30 countries.

Although the atom was once thought to be indivisible, nuclear fission involves just that, splitting an atom of a large atomic weight into two atoms of lower atomic weight. The element of choice, as used in nuclear power plants, is uranium – but not just any uranium. An element is defined by the number of protons in its nucleus and for uranium this is 92, a number known as its atomic number.

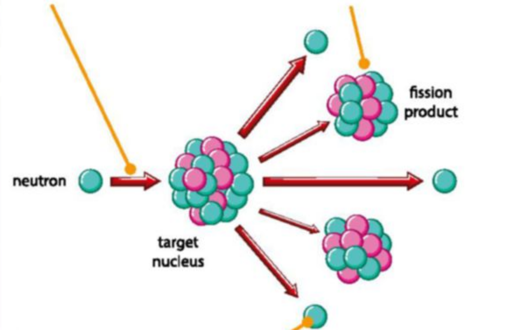
"Although the atom was once thought to be indivisible, nuclear fission involves splitting it"

Fission vs fusion

Fission and fusion are opposite nuclear reactions, but both can generate energy

Fission reaction
Fission is brought about when a neutron collides with a high atomic weight nucleus such as uranium-235.

Fission products
The result is two smaller nuclei – often barium and krypton in the case of uranium-235 fission – plus two or three neutrons.

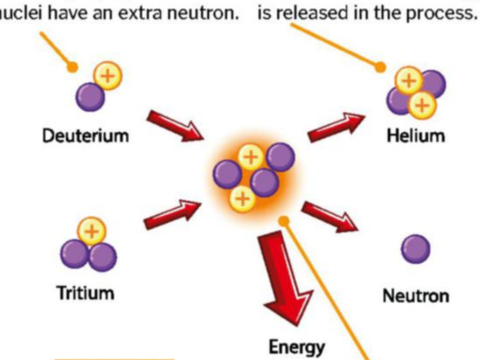


FISSION

Chain reaction
More neutrons are generated than the one taken to initiate the fission. These reach other uranium-235 nuclei, resulting in a chain reaction.

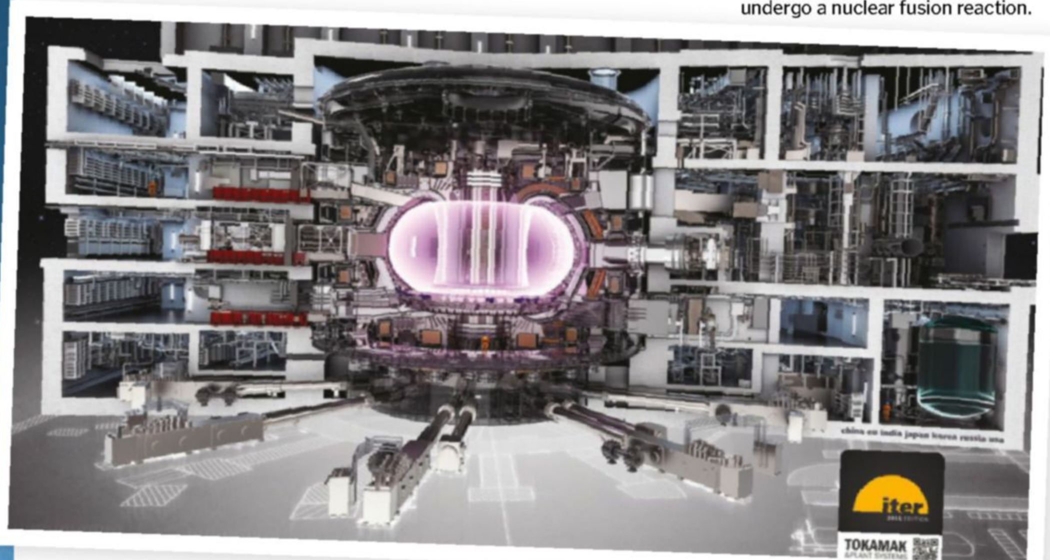
Deuterium and tritium
Deuterium nuclei contain one proton (yellow) and one neutron (purple). Tritium nuclei have an extra neutron.

Fusion products
Fusion generates a nucleus of a larger element (helium) and a neutron is emitted. Energy is released in the process.



FUSION

Fusion reaction
When brought together at over 100 million degrees Celsius, the deuterium and tritium nuclei undergo a nuclear fusion reaction.



The ITER project aims to deliver the first large-scale fusion reactor by 2035

Binding energy

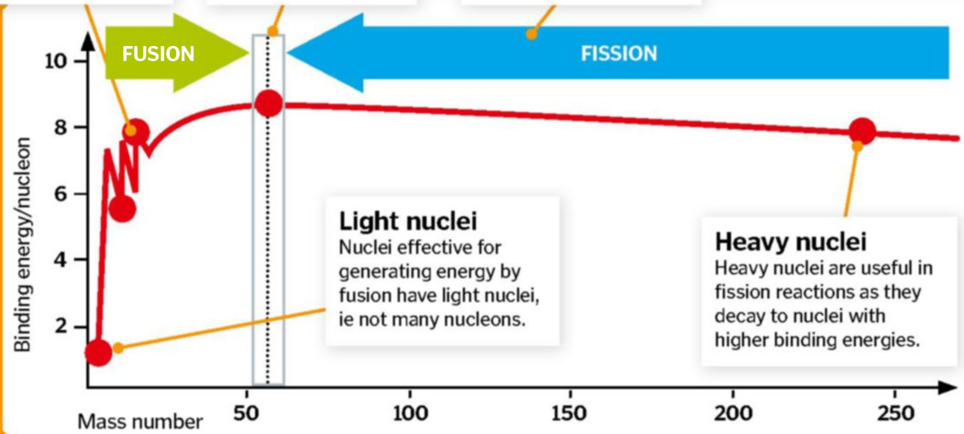
The binding energy is the energy required to separate a pair of nucleons (ie protons and neutrons). It varies with the number of nucleons in the nucleus (the atomic weight), rising to a maximum between about 50 and 70 nucleons. Because both the large fissile (capable of fission) nuclei and the small fusile (capable of fusion) nuclei have a smaller binding energy than that of the nuclei they become during fission or fusion, energy is released in the reaction.

The shape of the graph also explains why more energy is available from fusion than fission. Due to the particularly steep curve for small numbers of nucleons, there is a large difference between the binding energy of fusile nuclei (2H and 3H) and that of the result of the fusion (4He).

Energy release
Fusion causes light nuclei to become nuclei with a higher binding energy, releasing energy.

Stable region
Iron and the elements close to it in terms of atomic mass have tightly-bound nuclei.

Fission or fusion?
Lighter elements release energy by fusion, while heavier elements release it by fission.



Light nuclei
Nuclei effective for generating energy by fusion have light nuclei, ie not many nucleons.

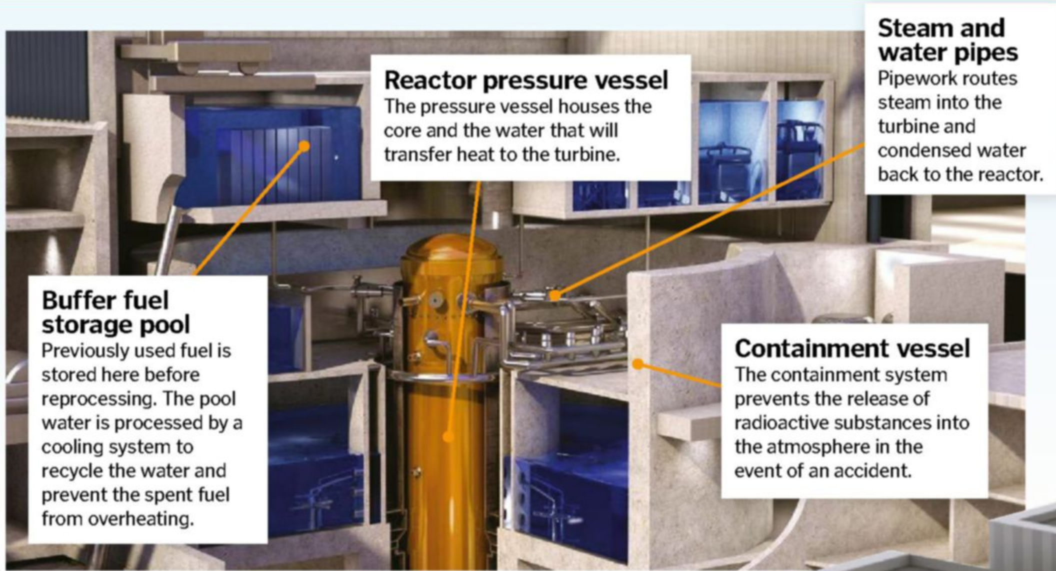
Heavy nuclei
Heavy nuclei are useful in fission reactions as they decay to nuclei with higher binding energies.

However, elements can exist in several forms, known as isotopes, which differ in the number of neutrons in their nucleus. Uranium isotopes include uranium-235 (otherwise denoted as 235U) and uranium-238 (238U), where the number is the atomic weight, which is the sum of the number of protons and neutrons. Naturally occurring uranium is about 99.27 per cent uranium-238 and only 0.7 per cent uranium-235 – not particularly useful for energy generation because uranium-235 is the isotope that can undergo fission (uranium-238 cannot sustain a fission chain reaction). To be useful as a fuel, therefore, the concentration of the fissile uranium-235 has to be increased in a process called enrichment. Because the chemical properties of the two main isotopes of uranium are very similar, enrichment is a lengthy process in which the concentration of uranium-235 is increased in steps. The enriched uranium used for power generation has about three to five per cent uranium-235.

Fission of uranium-235 occurs when neutrons are fired at it. The neutron is initially captured by the uranium-235, but this makes it highly unstable, causing it to split into two other elements, releasing energy in the process. Fission of uranium-235 can give rise to a whole range of by-products, although isotopes of barium and krypton are two of the most common. Most of these by-products are highly radioactive in themselves, so they, in turn, also decay. Crucially, though, the fission reaction also releases two or three neutrons, which are then free to collide with other uranium-235 atoms, and so cause them to undergo nuclear fission. This gives rise to a chain reaction, which means that the fusion reaction, once initiated, is self-sustaining. In fact, in a nuclear reactor, unless controlled, this process will result in the release of energy much too quickly, with disastrous consequences, as evidenced by the destruction of a reactor at the Chernobyl nuclear power station in 1986.

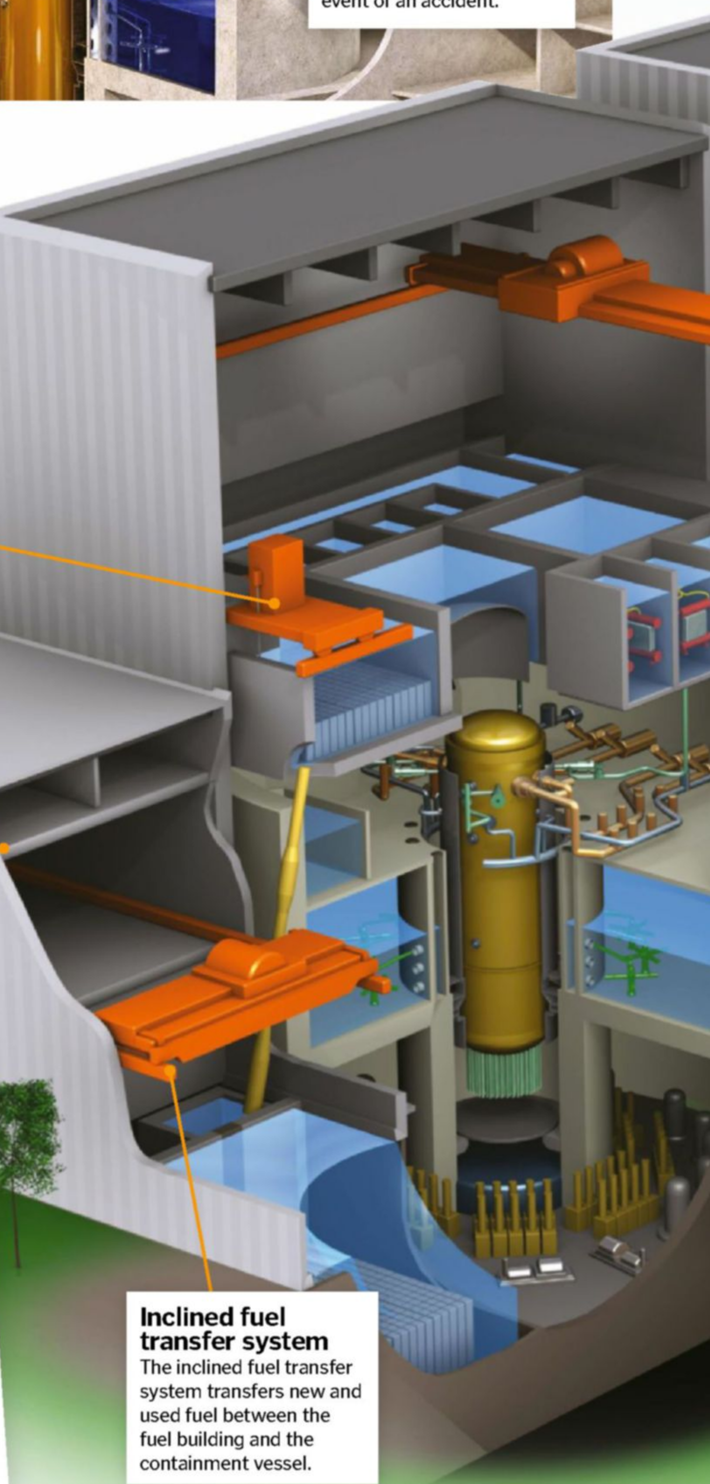
The solution is to use a material capable of neutron capture without itself undergoing fission, most commonly boron. These materials are fashioned into so-called control rods and housed in the reactor core. By raising and lowering the control rods, the neutron flux can be controlled to allow the fission reaction to take place while preventing a runaway situation, an eventuality called criticality. They also allow an emergency shut down of the reactor.

Discussion of nuclear power stations inevitably leads to talk of the various types of reactor, with names such as the pressurised water reactor, the boiling water reactor and the Magnox or gas-cooled reactor bandied around. At the highest level, though, all nuclear power

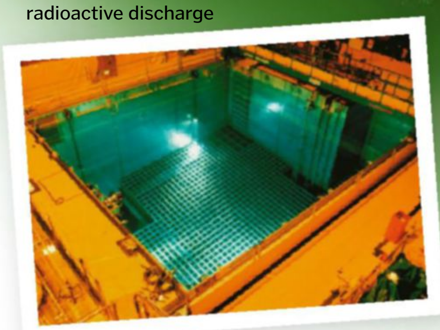


Inside a nuclear fission plant

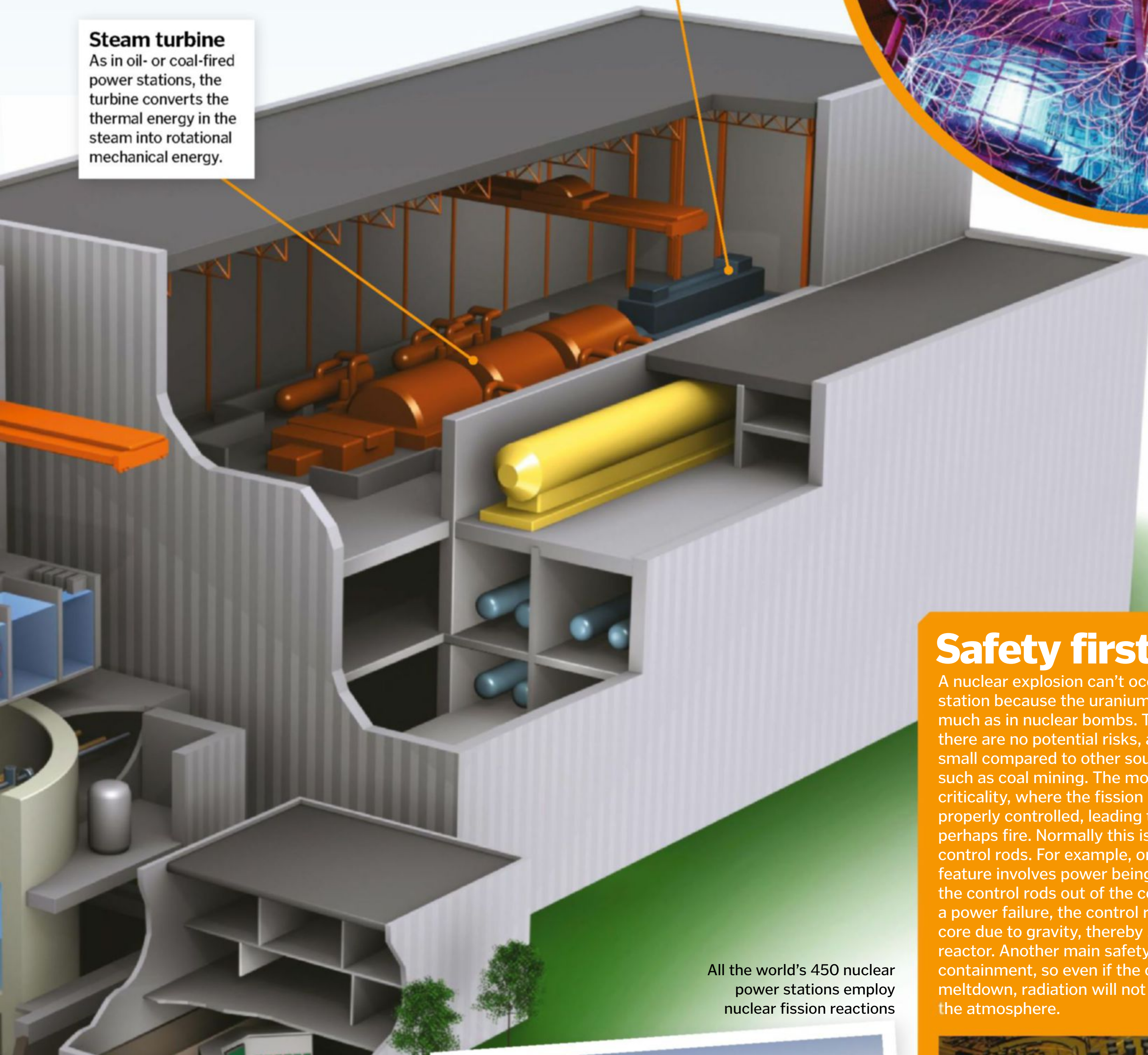
A tour of a power station based on GE Hitachi's Economic Simplified Boiling Water Reactor design

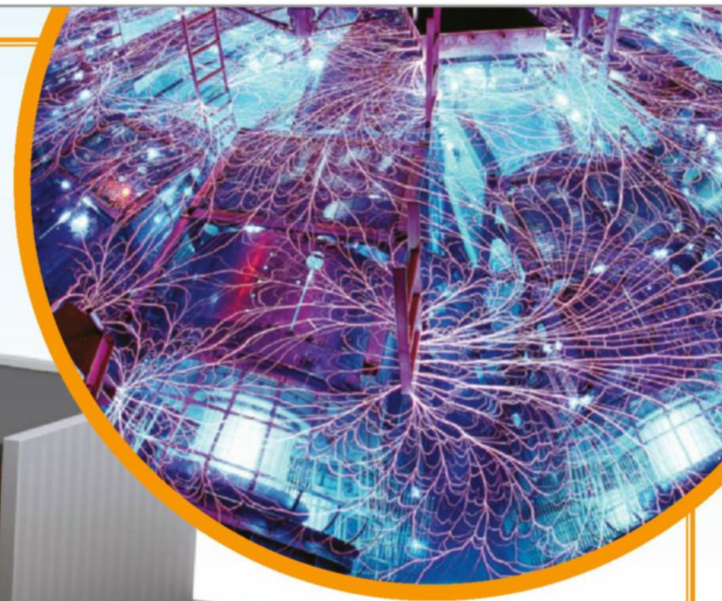


Spent fuel is stored underwater to prevent radioactive discharge



"The difference between reactor types relates to the way the heat is extracted from the core"





Sandia Laboratory's Z Machine is used for researching high temperatures and pressures as needed for nuclear fusion

All the world's 450 nuclear power stations employ nuclear fission reactions

Safety first

A nuclear explosion can't occur in a power station because the uranium isn't enriched as much as in nuclear bombs. This isn't to say there are no potential risks, although they're small compared to other sources of energy, such as coal mining. The most obvious risk is criticality, where the fission chain reaction isn't properly controlled, leading to overheating and perhaps fire. Normally this is prevented using control rods. For example, one clever safety feature involves power being needed to hold the control rods out of the core. In the event of a power failure, the control rods fall into the core due to gravity, thereby shutting down the reactor. Another main safety measure is containment, so even if the core suffers a meltdown, radiation will not be released into the atmosphere.

Control rods are essential in preventing criticality from occurring in a nuclear reactor

stations work in much the same way. The nuclear fission reaction generates heat, the heat turns water into steam and, from here on, things are the same as in a coal- or oil-fired power station. The steam drives a turbine, which in turn drives a generator that produces electricity.

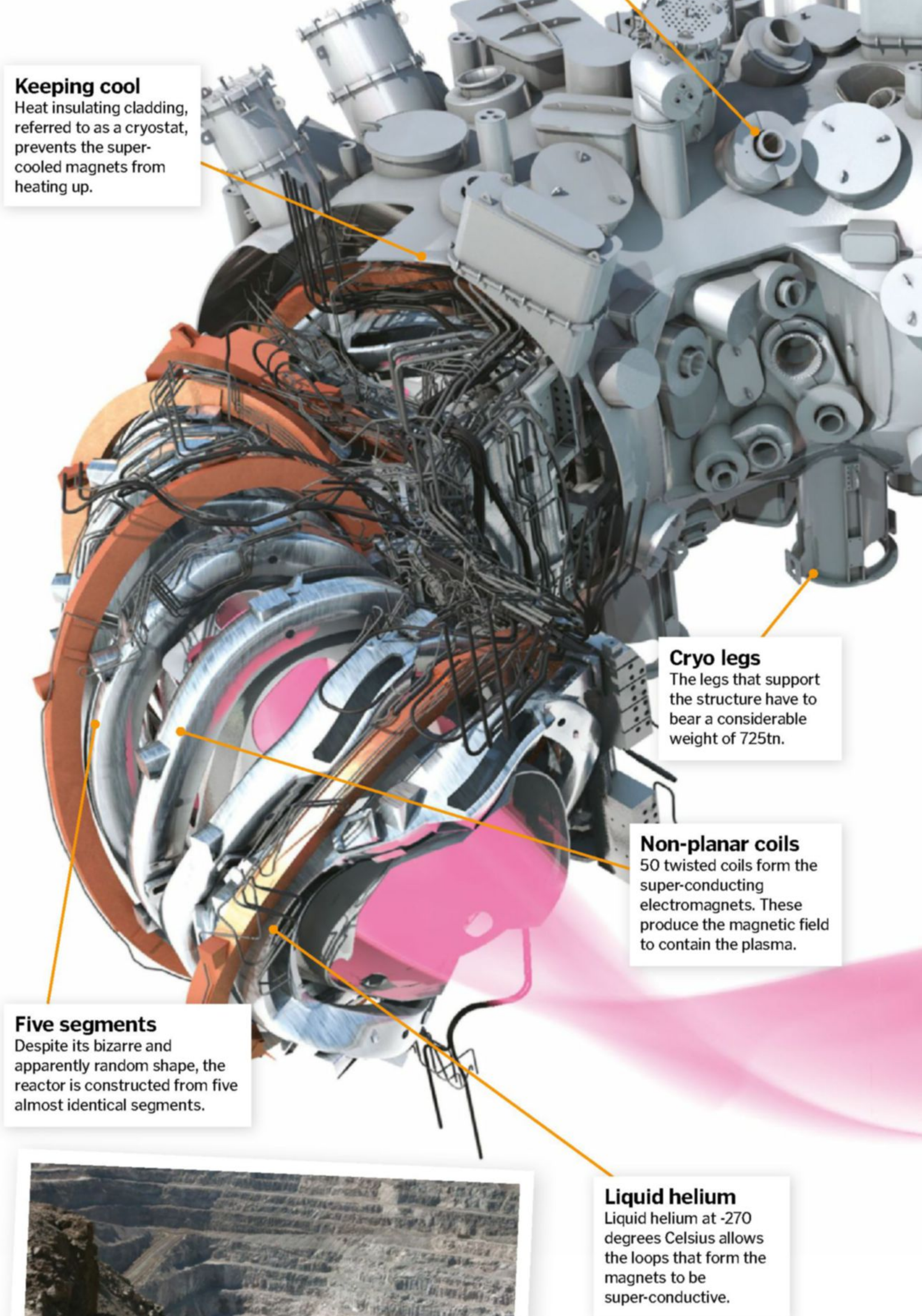
The difference between the various reactor types relates to the way the heat is extracted from the core. In the boiling water reactor, the water that is heated to produce the steam is pumped through the nuclear reactor. In the pressurised water reactor, on the other hand, to prevent contaminated steam entering the turbine, there are two water circuits. The primary water flows through the reactor, which gives up its heat to the secondary water in a heat exchanger, the secondary water turning to steam and driving the turbine. The advanced gas-cooled reactor, as favoured in the UK, is similar except that the primary circuit, which transfers heat from the reactor to the water in the secondary circuit, uses carbon dioxide instead.

So much for the current state of play, but the Holy Grail of nuclear power is fusion rather than fission. As the name suggests, nuclear fusion is the opposite of nuclear fission – two atomic nuclei merging to produce an element with a larger atomic mass. Again this generates energy; the plentiful energy that the Earth receives from the Sun is the result of a massive nuclear fusion reaction. One of the Sun's fusion reactions, and the one that has been the subject of most research, occurs between two isotopes of hydrogen, namely deuterium (hydrogen-2) and tritium (hydrogen-3) to produce helium. Fusion produces much more energy than fission and the by-products are not as radioactive, thereby reducing concerns over nuclear waste, plus the raw materials are potentially plentiful. Yet despite these benefits, there are some serious challenges to be met before fusion can form the basis for power generation. In particular, to initiate and maintain the reaction temperatures of over 100 million degrees Celsius are needed, and to hold the deuterium and tritium atoms together a magnetic field thousands of times that of Earth's own is required.

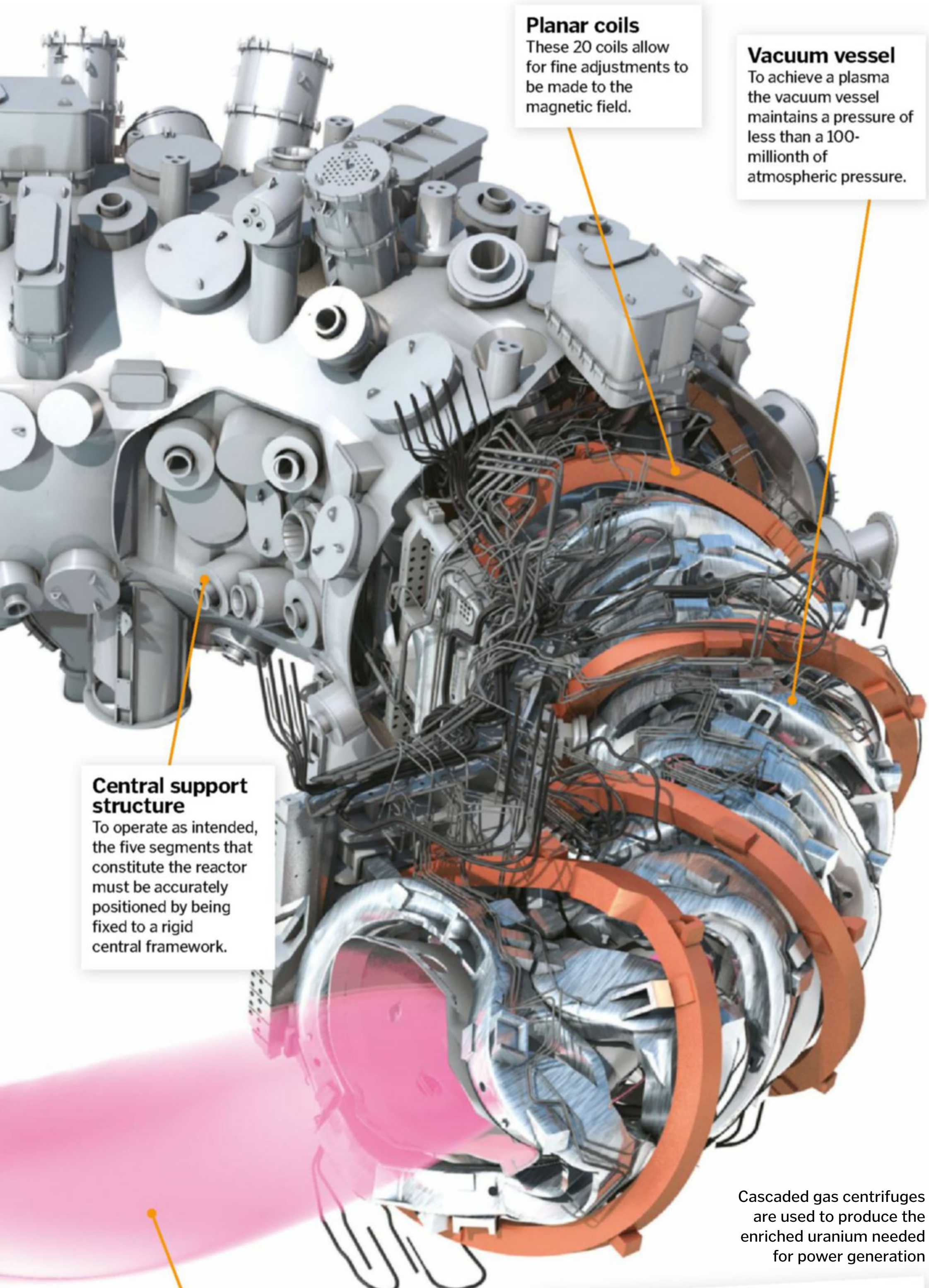
Burning fossil fuels generates greenhouse gasses, but nuclear fission – while producing about 11 per cent of the world's electricity without producing carbon dioxide – has its critics. While renewables will undoubtedly play an important role in the future, the potential benefits of fusion, should it ever come to fruition, can't be ignored. Currently, a project involving China, the European Union, India, Japan, South Korea, Russia and the United States is causing considerable interest. Called ITER, the aim is to produce the first operating large-scale fusion reactor by 2035, so watch this space.

The Wendelstein 7-X fusion reactor

The engineering wizardry behind the world's largest fusion reactor



The Rossing Mine in Namibia is one of the world's largest producers of uranium

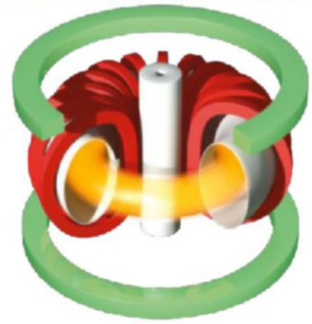


Comparing alternative fusion reactors

Most fusion reactor designs are toroids with external coils that generate a magnetic field needed to prevent the high temperature plasma from touching the reactor walls. But the magnetic field must have a twist.

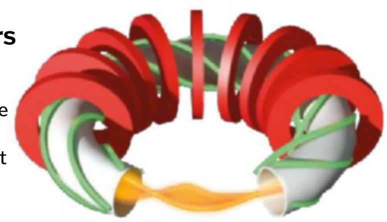
Tokamaks

In tokamak reactors, a current flows through the plasma to create the twist.



Stellarators

In stellarator reactors, the whole machine is twisted to achieve a twist in the field.



The challenge of fusion

Research into nuclear fusion started decades ago and, for most of that time, commercial applications were thought to be 30 or 40 years away. So why are we getting no closer to a nuclear fusion power station? What's the challenge that's holding it at bay?

Unfortunately, there's no one single challenge but many. One of the most significant is that the necessary temperature is so high that large amounts of energy are needed. For many years experimental fusion reactors used more energy than they generated. A breakthrough came in 2014 at the Lawrence Livermore National Laboratory in the US, when a reactor generated 1.7 times more energy than it consumed. But the reactor was a small-scale device and the challenges are compounded as the technology is scaled up.

It's interesting to note that an aim of the ITER fusion reactor, scheduled for 2035, is to generate 500 megawatts but only use 50.

Lawrence Livermore's National Ignition Facility conducts fusion experiments using ultra-powerful lasers to heat and compress hydrogen fuel

Cascaded gas centrifuges are used to produce the enriched uranium needed for power generation

"The Holy Grail of nuclear power is fusion rather than fission"

Types of headache

What's the difference between a migraine, a tension headache and a cluster headache?

There are dozens of different types of headaches, but according to the NHS, the most common is a 'tension' headache, which affects the whole of the head with a dull, tight pain associated with stress, dehydration and muscle tension.

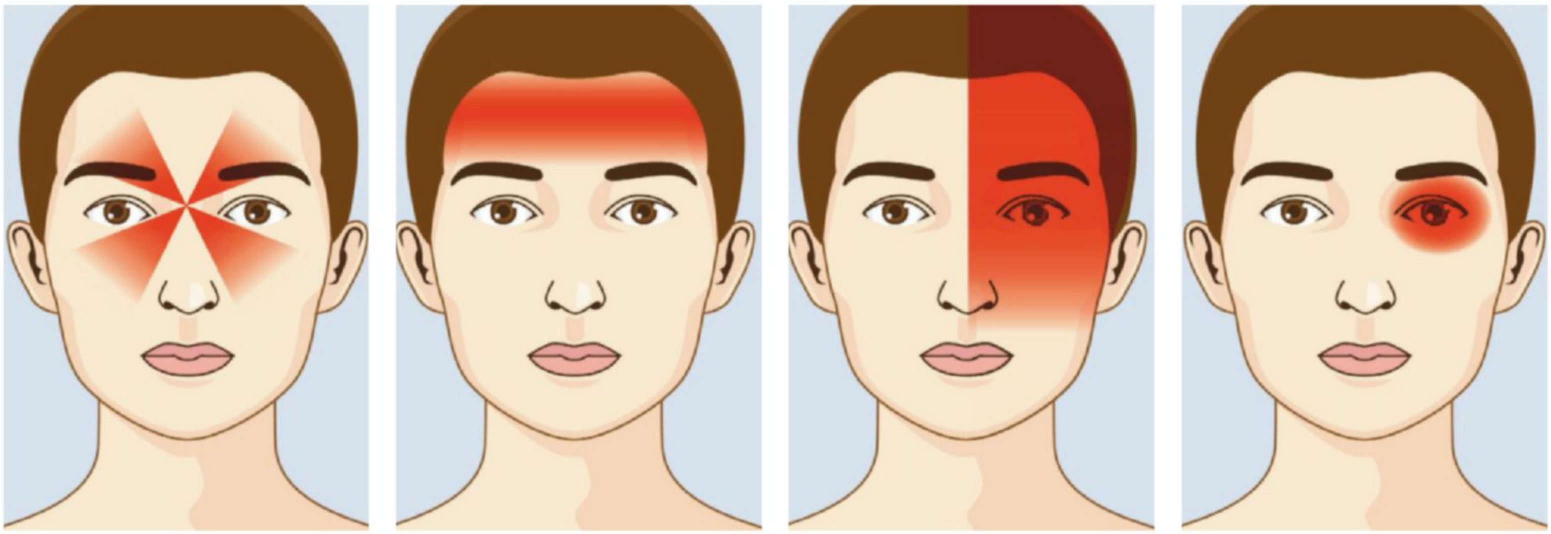
Migraines are more intense, and less common, striking one side of the head at a time and causing intense throbbing. They are thought to be linked to changes in nerve activity and blood-flow inside the brain. Hormonal changes can also cause headaches, and allergies and infections can cause pressure-related headaches due to congestion in the sinuses.

Rarely, a headache can be caused by something more serious. If the pain is sudden and intense, or is accompanied by a fever, rash, or changes in speech, memory or mobility, it's important to contact a doctor. Such headaches could be sign of a stroke or brain tumour.


Some people experience vision disturbance called an 'aura' before a migraine

Top four headaches

Some of the most common headache types explained



Sinus
Sinus headaches most often accompany an infection, and are linked to increased pressure either side of the nose and above the eyes due to mucus blockage.

Tension
Tension headaches tend to affect both sides of the head, and consist of a tight feeling. They are thought to be related to stress, muscle strain and dehydration.

Migraine
Characterised by intense, throbbing pain on one side of the head, migraines can affect people's vision or make them feel sick or sensitive to noises and lights.

Cluster
Cluster headaches affect one eye, and are associated with severe pain, nasal congestion and tear production. This type of headache tends to recur several times.

How clean are your teeth?

Discover how dental disclosing tablets reveal the hidden plaque that coats your gnashers

Your teeth might look squeaky clean after you've finished your morning brush, but plaque can be difficult to spot. It's a sticky film of bacteria and sugar that is constantly forming across the surface of the enamel and below the gumline, and if left long enough it can harden to form a substance called tartar, which is extemely difficult to remove.

Dental disclosing tablets can reveal the plaque that you might have missed when brushing. These chewable pills contain vegetable dyes that stick to the plaque and stain it a bright colour, making the deposits easier to see. The bacteria in the plaque live in a web of molecules called a matrix, and the dye becomes trapped in this network, revealing the areas of the teeth that still need to be cleaned. They are available at chemists and can be used at home to help you to spot problem areas that you might need to pay special attention to when you clean your mouth.

Research has shown that people tend to end up with cleaner teeth after a dental disclosing tablet makes them aware of the plaque that still remains after their usual brush.


Disclosing tablets reveal the plaque that you missed when brushing your teeth

Anatomy of facial expressions

Does it really take more muscles to frown than to smile?

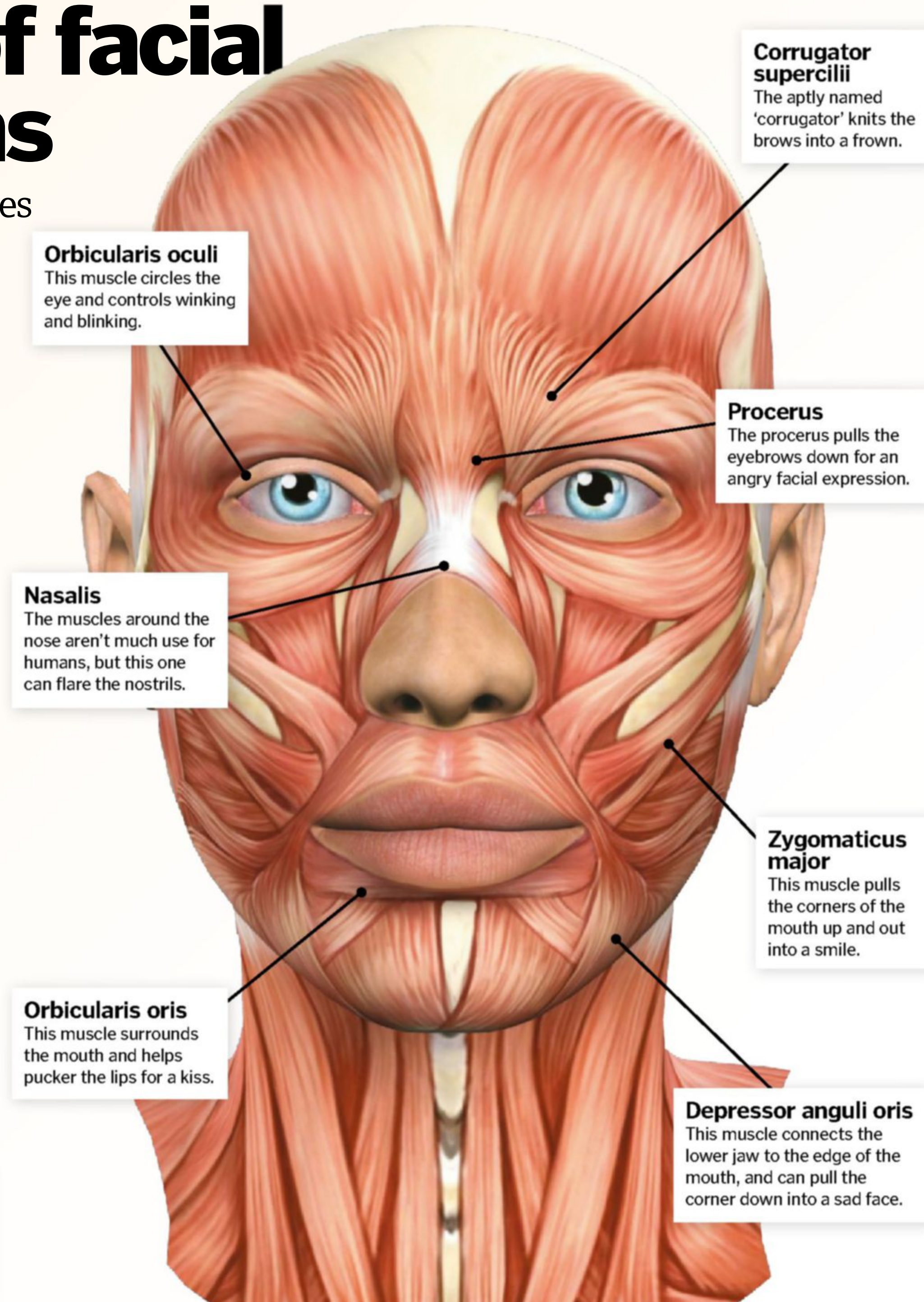
The 43 muscles of the face sit just under the skin. At one end, they are attached to bone, or sheets of tissue known as fascia, and, unlike any other muscles in the body, they join directly to the skin at the other end.

We can sort our facial muscles into three groups: the orbital group, the nasal group and the oral group. Together, they enable us to make four core expressions: happy, sad, afraid and angry, and over 20 combined expressions.

There are two muscles in the orbital group – the orbicularis oculi, which surrounds the eye socket, and the corrugator supercilii, which controls the eyebrow. The first is responsible for blinking and winking, and the second contracts to pull the eyebrows together into a frown.

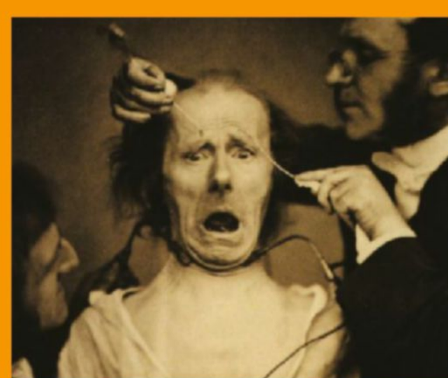
We don't have a lot of control over the movement of the muscles around our nose, but the nasalis is the biggest, and with help from the depressor septi it flares the nostrils. The procerus runs from the top of the nose to the forehead, and it can pull the eyebrows down.

Finally, there are the oral muscles. The two major ones are the orbicularis oris, which surrounds the mouth and contracts to purse and pucker the lips, and the buccinator running under the cheekbone. There are also two groups of smaller muscles, the upper and the lower groups, which control the fine movements of the facial tissue to form smiles and frowns.



Deciphering the face

Benjamin Amand Duchenne was a French physiologist in the 19th century, and his macabre experiments attempted to reveal the muscles responsible for different facial expressions. He wired test subjects up to galvanic probes, which delivered small electric shocks through the skin to the underlying muscles. He tried his experiment on five test subjects: a girl, a young man and woman, and an older man and woman. He captured pictures of the expressions made when different parts of the face were stimulated. Charles Darwin was so taken with the images that he later used them in his own experiments to find out whether people could read the emotions of the test subject just by looking at the expressions that their faces were pulling.



This photo shows Duchenne's experiment in action

How fire extinguishers work

The science helping people to fight fires fast

To fight fire, first you need to understand what makes it burn. There are three main components that help keep a fire going: fuel, oxygen and heat. Fuels can be any kind of combustible or flammable material. When extreme heat is applied to this fuel, a chemical reaction takes place with the oxygen in the air. This chemical reaction produces water, carbon dioxide, other waste gases and a lot of heat.

In order to put fires out, one or more of the three main components needs to be removed. If you can cut off oxygen to the fire, it will stop burning – that's why covering a burning pan with a fire blanket puts out the flames. Making the fuel cold will also work, which is why throwing water on a small fire will usually put it out. And if you stop adding fuel to a fire then it eventually burns itself out.

Fire extinguishers work well because they remove one or two of these components from the fire. There are different kinds of extinguishers depending on the type of fire you're fighting. Using the right one is important, as is knowing the science behind how they work.

Handle
Pressing the handle activates the extinguisher. Each one should be checked regularly to ensure it's ready for use.

Hose
The water flows out of the siphon tube and into the hose, allowing the user to direct the water onto the fuel of the fire.

Safety pin
The safety pin must be removed before the extinguisher can be used, preventing accidents.

CO_2 canister
When the handle is pressed, the valve to the CO_2 canister is opened, increasing the pressure inside the extinguisher.

Water
When the pressure increases the water is pushed out of the extinguisher via the siphon tube.

Siphon tube
The tube is designed to stop water leaking out of the extinguisher accidentally but let water up it when the CO_2 is released.

Fire extinguishers come in different sizes and are colour coded depending on what extinguisher agent is inside

Extinguisher types

Water
The water quickly cools the fuel, stopping the fire by removing the heat. Spray it directly onto the fuel, not the flames.

For use on...
Wood, paper, textiles etc.

DO NOT use on...
Flammable liquids
Live electrical equipment

Dry powder
This powder, often similar to baking soda, doesn't burn. Instead, it smothers the fuel and removes the oxygen from the fire.

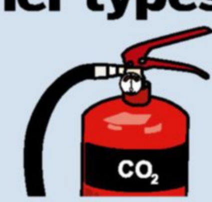
For use on...
Wood, paper, textiles etc.
Flammable liquids
Gaseous fires
Live electrical equipment

DO NOT use on... N/A

Foam
This foam is similar to the dry powder. When heated, it changes state and releases CO_2 to help smother the fire.

For use on...
Wood, paper, textiles etc.
Flammable liquids

DO NOT use on...
Live electrical equipment



Carbon dioxide
This extinguisher releases CO_2 in gas form. CO_2 is heavier than oxygen, so it displaces the oxygen that is fuelling the fire.

For use on...
Flammable liquids
Live electrical equipment

DO NOT use on...
Do not use in a confined space

Vapourising liquids
Vapour-based extinguishers smother the oxygen that fuels a fire. Extinguishers using halon are largely banned since halon was linked to ozone depletion.

For use on...
Wood, paper, textiles etc.
Flammable liquids

DO NOT use on...
Do not use in a confined space

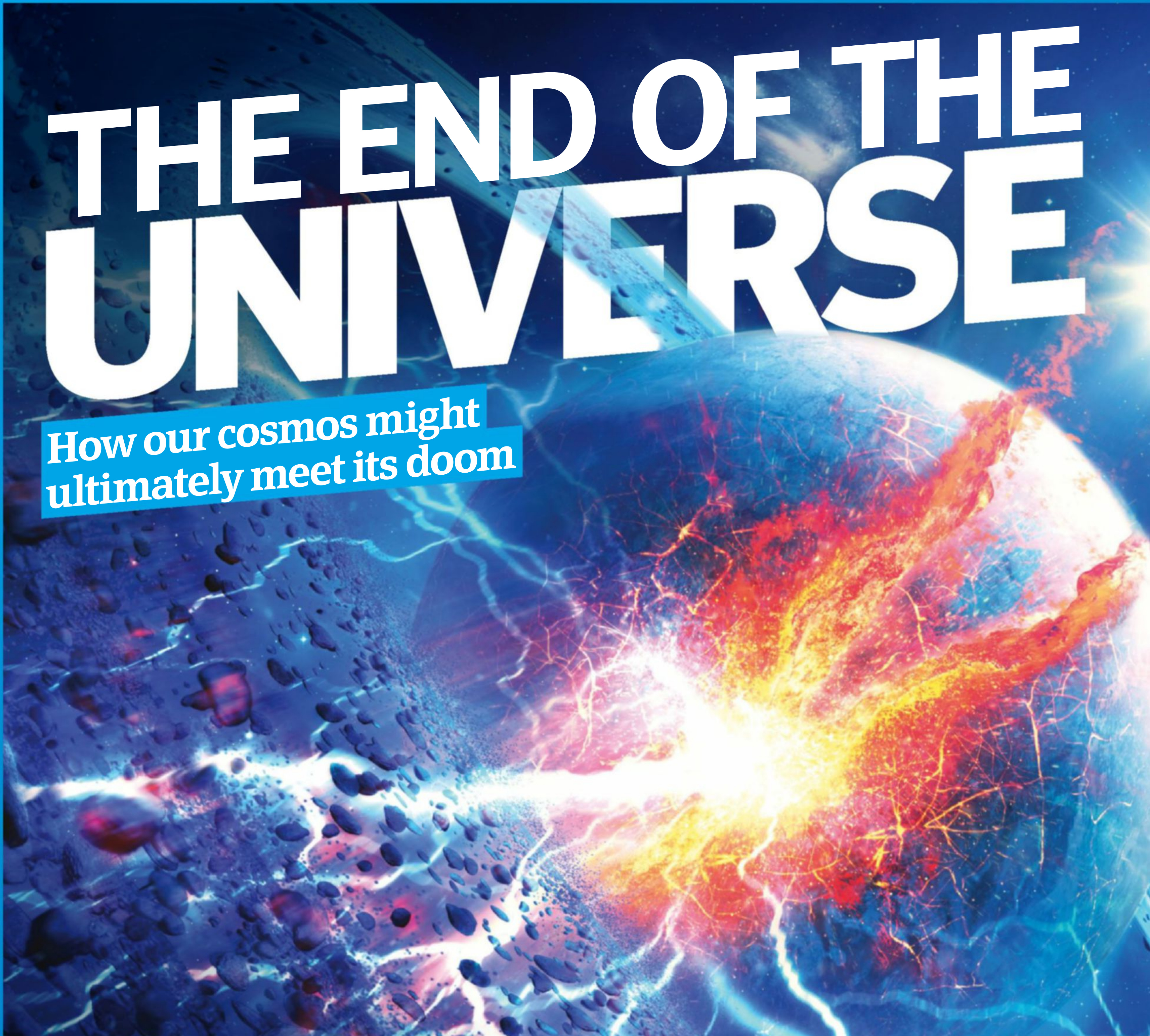
Wet chemical
The chemical is especially effective for putting out cooking oil fires, as it forms a soap-like solution that smothers the fire.

For use on...
Wood, paper, textiles etc.
Cooking oil fires

DO NOT use on... N/A

THE END OF THE UNIVERSE

How our cosmos might ultimately meet its doom



If you're hoping that the universe as we know it is going to be around forever, then we're afraid we've got some bad news for you. One day far in the future, our cosmos as we know it will no longer exist. But how it gets there and what happens next is up for debate.

For centuries many believed that our universe was static. We thought it was here, always had been here, and wasn't going anywhere. But in 1929, just six years after he discovered the first galaxy, American astronomer Edwin Hubble discovered that all galaxies were moving away from each other . Thus, he correctly assumed that the universe was expanding.

Prior to this, Albert Einstein had been working on his theories of relativity. In 1917, he postulated that there might be a force permeating throughout the entire universe, which he called the Cosmological Constant. Later, he would call this his "biggest blunder", as he rejected his own theory.

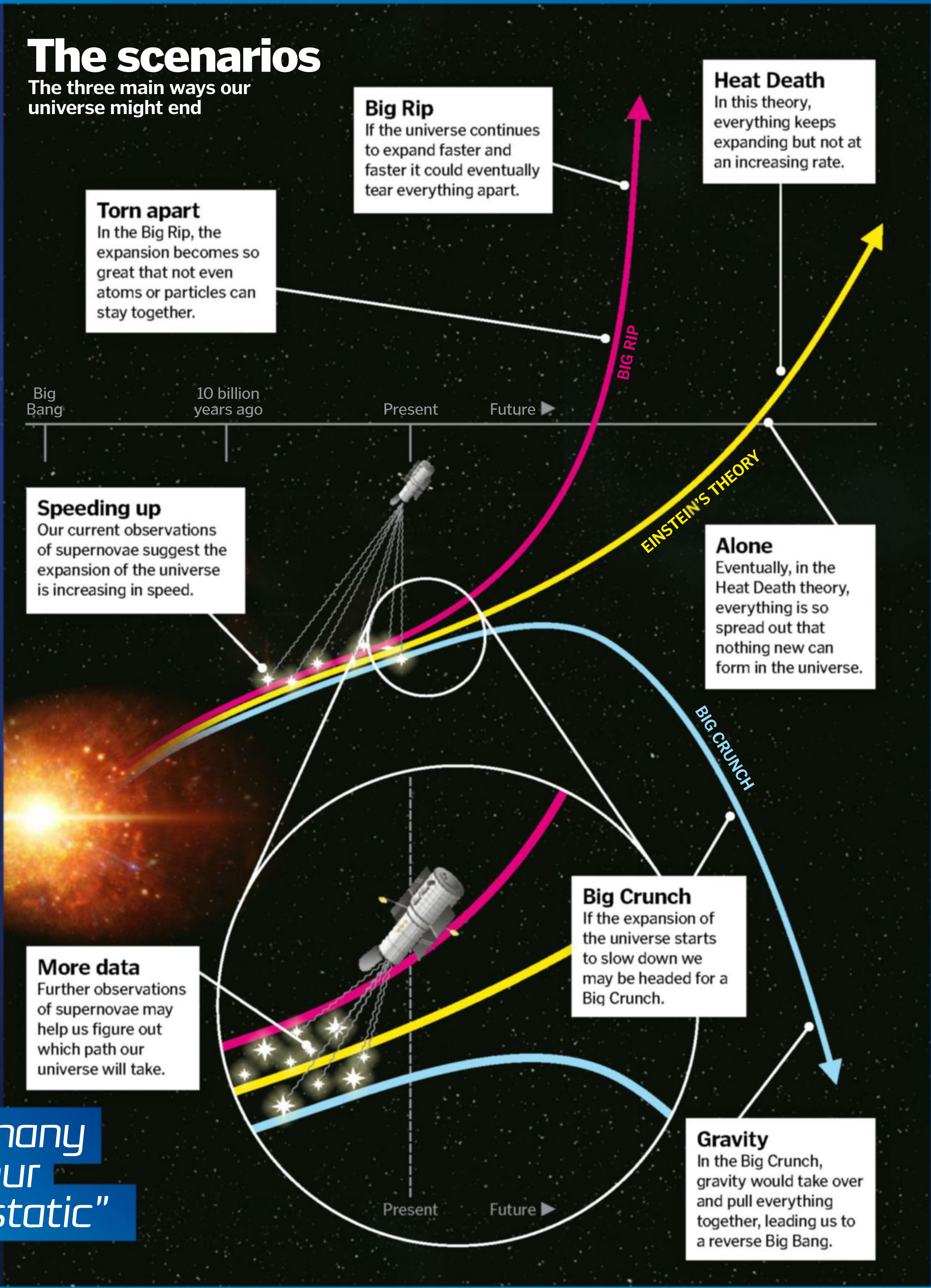
But he was not necessarily wrong. While Hubble found that the universe was expanding, it was not until 1998 that an even more shocking discovery was made – the universe was expanding at an accelerating rate. This means things are moving away from each other faster and faster. It's a bit counter-intuitive; similar to throwing a ball in the air and it never returning to the ground.

Hubble saw that galaxies were moving faster from us the further away they were, predicted in 1927 by Belgian astronomer Georges Lemaître. He initially calculated a value for this, which is now known as the Hubble Constant. Today, we know this to be that for every megaparsec (3.3

“For centuries many believed that our universe was static”

The scenarios

The three main ways our universe might end



Big Rip
If the universe continues to expand faster and faster it could eventually tear everything apart.

Heat Death
In this theory, everything keeps expanding but not at an increasing rate.

Torn apart
In the Big Rip, the expansion becomes so great that not even atoms or particles can stay together.

Speeding up
Our current observations of supernovae suggest the expansion of the universe is increasing in speed.

Alone
Eventually, in the Heat Death theory, everything is so spread out that nothing new can form in the universe.

Big Crunch
If the expansion of the universe starts to slow down we may be headed for a Big Crunch.

More data
Further observations of supernovae may help us figure out which path our universe will take.

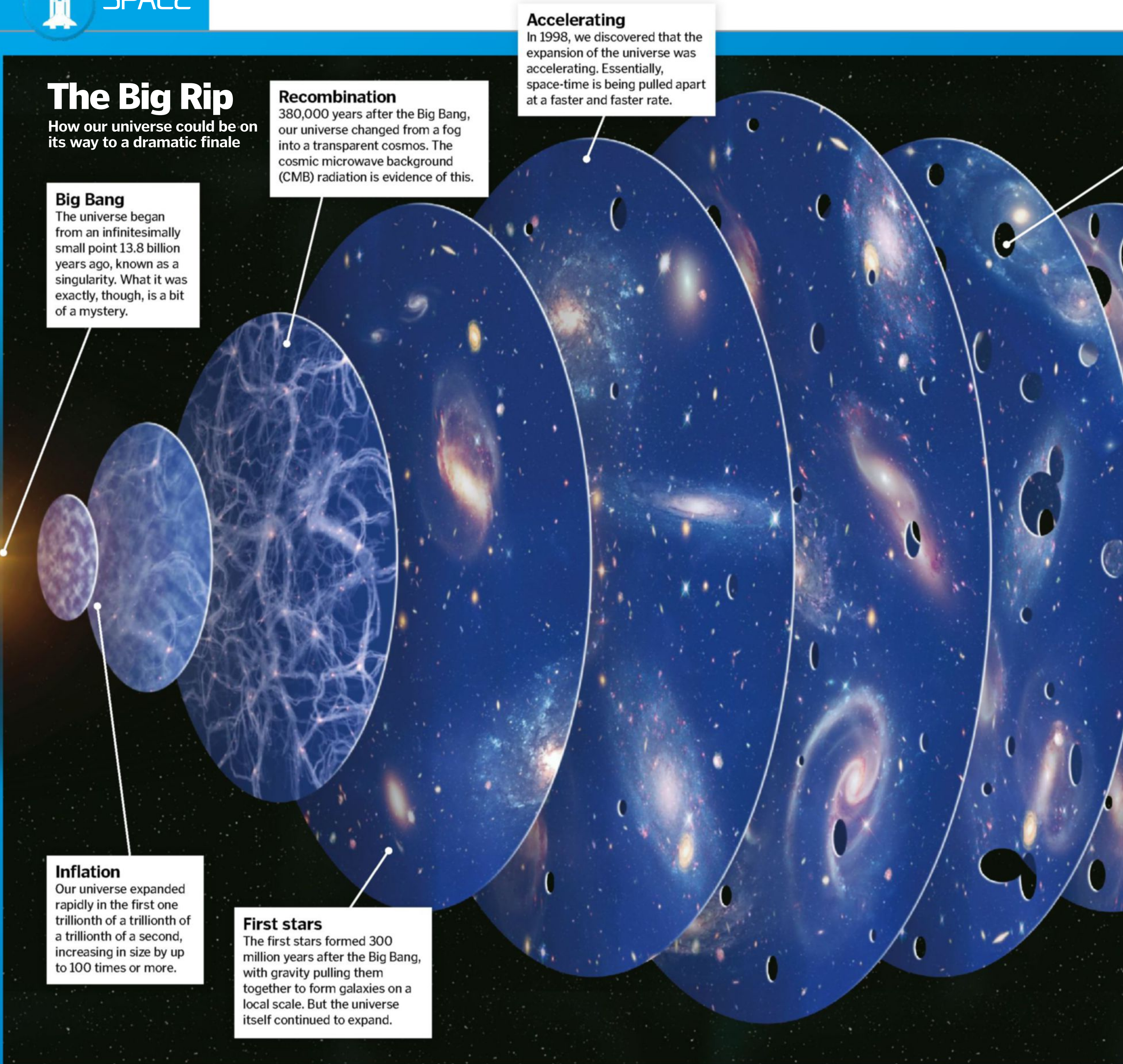
Gravity
In the Big Crunch, gravity would take over and pull everything together, leading us to a reverse Big Bang.

million light-years) you travel in the universe, the rate of expansion is about 70 kilometres per second, give or take a few kilometres depending on which of several theories is correct. So, if you had two people floating in space with otherwise no velocity and separated by a megaparsec, they would move away from each other at this speed.

The effect is small, but over large distances it really adds up – consider that our observable universe is about 28.5 gigaparsecs, or 93 billion light years, across. So the galaxies furthest from us are moving much faster than those nearby. What's more, this is not limited to us. Anyone in any galaxy would observe the same effect. Space-time itself is stretching, and there's no central point everything is moving away from.

To explain this accelerated expansion, astronomers came up with something called dark energy. Although we've never actually found it, it is thought to be a mysterious force that permeates the universe. Sound familiar? Yes, it's remarkably similar to Einstein's Cosmological Constant. Maybe the great physicist didn't make a blunder after all.

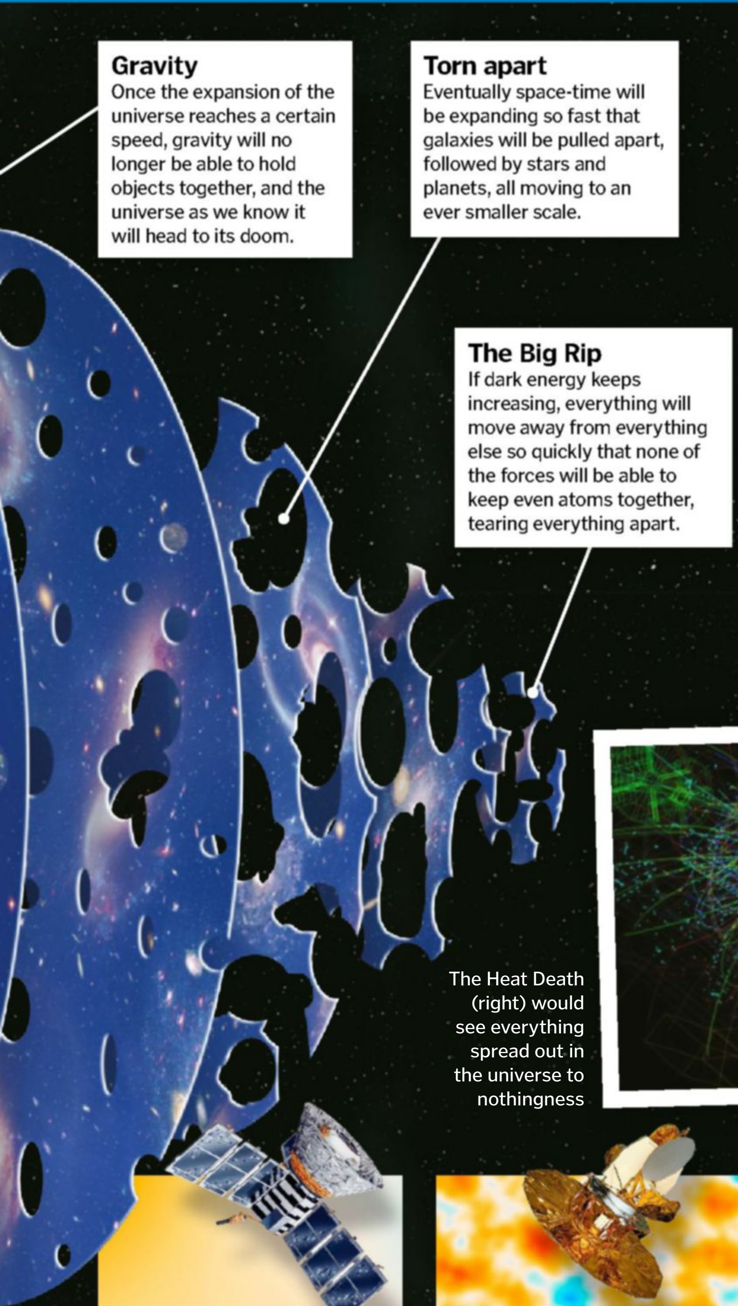
In fact, dark energy is estimated to make up about 68.3 per cent of the total energy in the universe, the rest being taken up by similarly mysterious (but unrelated) dark matter, 26.8 per cent, and regular (baryonic) matter, 4.9 per cent. It's very difficult to explain, though, other than that it seems to be there based on our calculations on how fast the universe is expanding. One theory is that it is a property of space itself, similar to Einstein's idea. It could also be some sort of fluid or field, but again, we really just don't know.



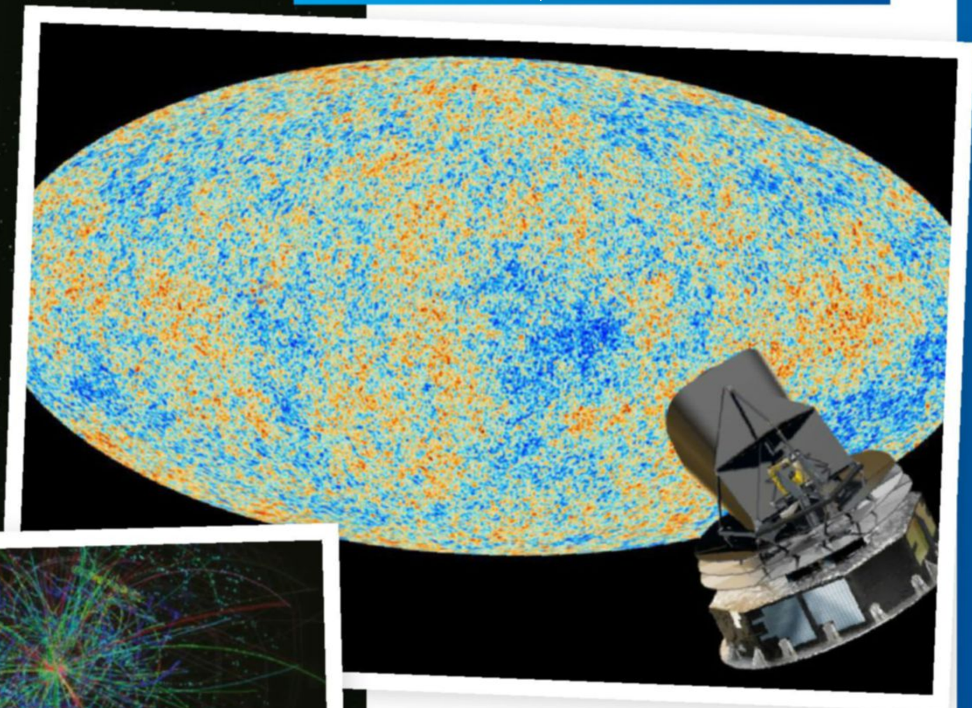
However, based on the effects it is having, we can take a pretty good stab at what will happen to the universe next, and it really depends on how the quantity of dark energy changes over time. The predominant theory at the moment is known as Heat Death, or the Big Freeze. This assumes that the expansion of the universe will continue at its current rate forever. This means that, over time, all matter and radiation will become so spread out that nothing new can form in the universe, and it becomes flat and empty, known as maximum entropy.

Stars and planets form when clouds of dust and gas gradually coalesce over time. When a star explodes, it creates new material that leads to the formation of new objects. But the process is not 100 per cent efficient. Each time, matter and energy is lost into the fabric of space, and so, eventually, no more stars will be able to form.

In this scenario, things will gradually die out because matter will be so spread out that nothing can come together to form. Stars like our Sun have a lifetime of only 10 billion years or so, but cooler objects like red dwarfs can last much longer. In fact, some predictions suggest they can continue burning fuel for trillions of years. If the universe ends in a Heat Death, these will be the last stars to go out. But they will be outlasted by black holes, which emit radiation (known as Hawking radiation) due to the effects of quantum mechanics. The most massive black holes are expected to continue doing this for 10 to the power of 100 (that's 10 followed by 100 zeroes, known as a 'googol') years from now, meaning that long after all the other lights have burned out, black holes will be the last to go.

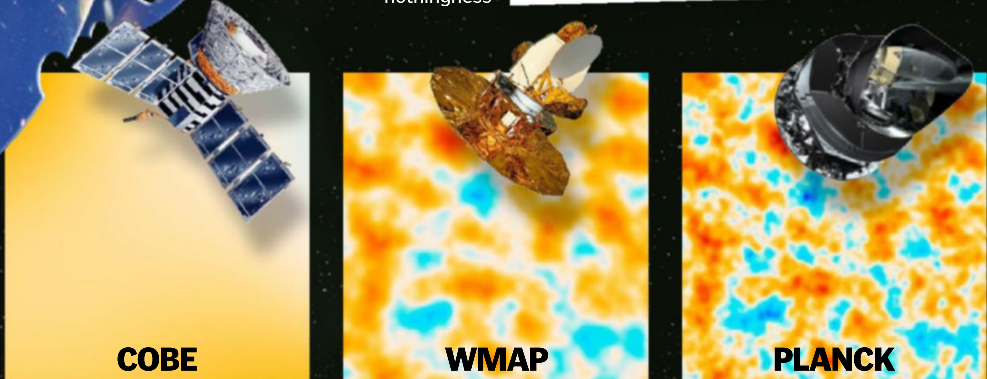


The cosmic microwave background (CMB) radiation as seen by the Planck observatory



> "Humanity probably won't be around to see the end of the universe"

The Heat Death (right) would see everything spread out in the universe to nothingness



Planck's observations have revealed the cosmic microwave background in greater detail than ever before

Studying the end of the universe

Our best way of studying the fate of the universe is by looking at its past. Launched in 2001, NASA's Wilkinson Microwave Anisotropy Probe (WMAP) was used to study the cosmic microwave background (CMB), which dates back to 380,000 years after the Big Bang.

It used this to estimate the age of the universe at 13.77 billion years old. Using this, we've been able to better map the universe today, and work out where we came from. It also determined that dark energy makes up 71.4 per cent of the universe – an astonishing amount, considering we don't really know what it is.

But ESA's Planck observatory recalculated the age of the universe in 2013, and found it to be slightly different – 13.82 billion years old. It also found it was expanding a bit slower than we expected, and found dark energy made up 68.3 per cent.

There is still much we don't know about the past, present and future of our universe. Slowly but surely, though, we're painting a fascinating picture.

A somewhat similar theory to Heat Death is the Big Rip, which considers what would happen if the universe continues to expand but at a faster and faster rate. In the Big Rip, eventually the universe will be expanding so fast that it will tear matter and atoms apart. We should note here that at the furthest reaches of the universe relative to us, some galaxies are already moving away from us faster than the speed of light. We know, that's technically impossible in a vacuum, but it's a property of space-time itself. It's that pesky Hubble Constant again.

In our modern universe, the forces of gravity, electromagnetism and the strong nuclear force keep atoms and matter together. But in the Big Rip, the expansion of the universe accelerates to such a speed that these forces can no longer dominate. The first to go will be galaxies, which will spread apart until their stars are drifting alone. Then, the stars and planets will be ripped apart by the expansion, and finally atoms and particles themselves will no longer be able to stay together. Thus, everything will be ripped apart from everything else. There will be absolutely nothing in the universe. One recent estimate suggests the Big Rip could occur as soon as 2.8 billion years from now. As mentioned, it will depend on the amount of dark energy and the effect it's having on the universe.

This brings us to the third, and perhaps most optimistic, scenario. The Big Crunch looks at the idea that the expansion of our universe might eventually start to slow down due to a decrease in the amount of dark energy. As a result, gravity would become the dominant force in the universe. Over many, many years, the galaxies

would start to move towards each other again.

Eventually, things would start to get really close together as the universe moved towards an opposite Big Bang. About 1,000 years before everything merged together, the temperature of the universe would be comparable to being on the surface of a star. Matter would be squashed together into a giant supermassive black hole, which may also collapse in on itself. The universe would be crushed to an infinitesimally small point.

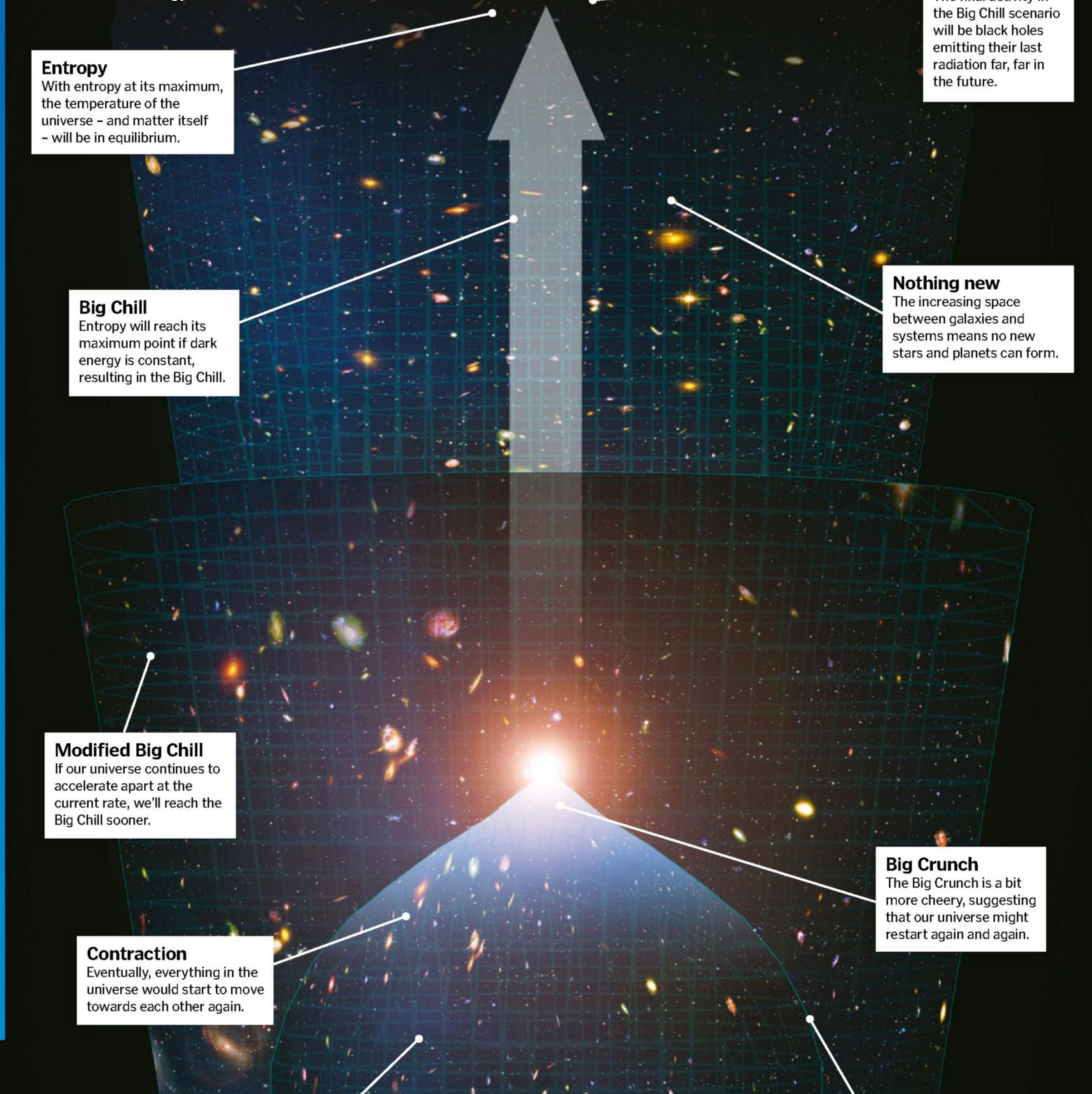
Some theories go further and suggest this could be followed by a Big Bounce, with a new Big Bang occurring, giving birth to a similar universe. It's possible that this has actually happened many times before, perhaps an infinite amount. We don't have any evidence for this, but if true it could mean our universe is eternal, so it's not all bad.

We mentioned the observable universe earlier, and unfortunately that's going to have a limiting factor on how we study the cosmos. We can only see a finite number of light years away, and even those galaxies at the edge of our vision are starting to disappear from sight because of the accelerated expansion of the universe. It's going to be difficult to work out what's going to happen.

At the moment, Heat Death looks the most likely scenario. And while that might be a bit depressing, don't worry too much. Our Sun will expand into a red giant in 5 billion years, and it may consume Earth in the process. At the very least, it will likely destroy any life remaining on our planet. So, unless we've colonised other worlds in the galaxy by then, humanity probably won't be around to see the end of the universe anyway.

Fates of the universe

At the end of the day, it all comes down to dark energy



Entropy
With entropy at its maximum, the temperature of the universe – and matter itself – will be in equilibrium.

10^{100} years from now
The final activity in the Big Chill scenario will be black holes emitting their last radiation far, far in the future.

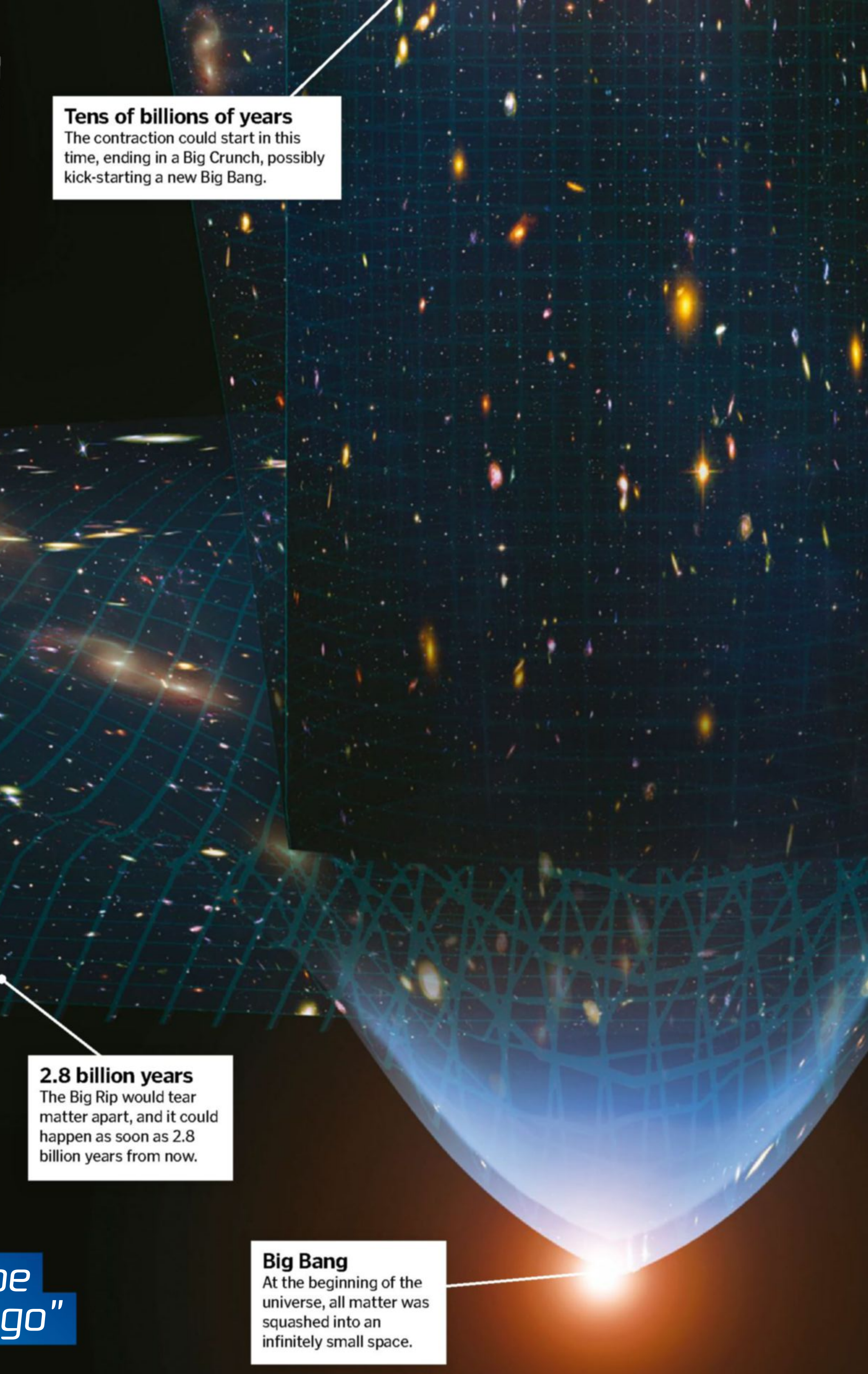
Big Chill
Entropy will reach its maximum point if dark energy is constant, resulting in the Big Chill.

Nothing new
The increasing space between galaxies and systems means no new stars and planets can form.

Modified Big Chill
If our universe continues to accelerate apart at the current rate, we'll reach the Big Chill sooner.

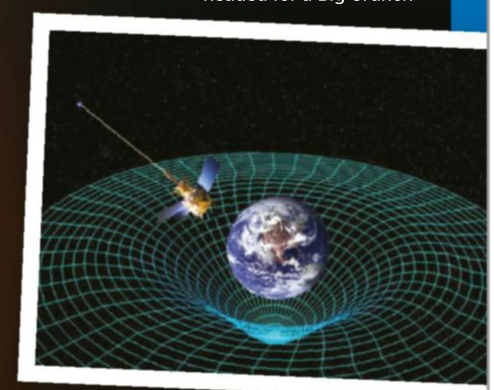
Big Crunch
The Big Crunch is a bit more cheery, suggesting that our universe might restart again and again.

Contraction
Eventually, everything in the universe would start to move towards each other again.




Telescopes have confirmed the expansion of the universe is accelerating


In the Heat Death scenario, black holes will be the last to die, losing energy via Hawking radiation


If gravity takes control we could be headed for a Big Crunch

"Black holes will be the last thing to go"

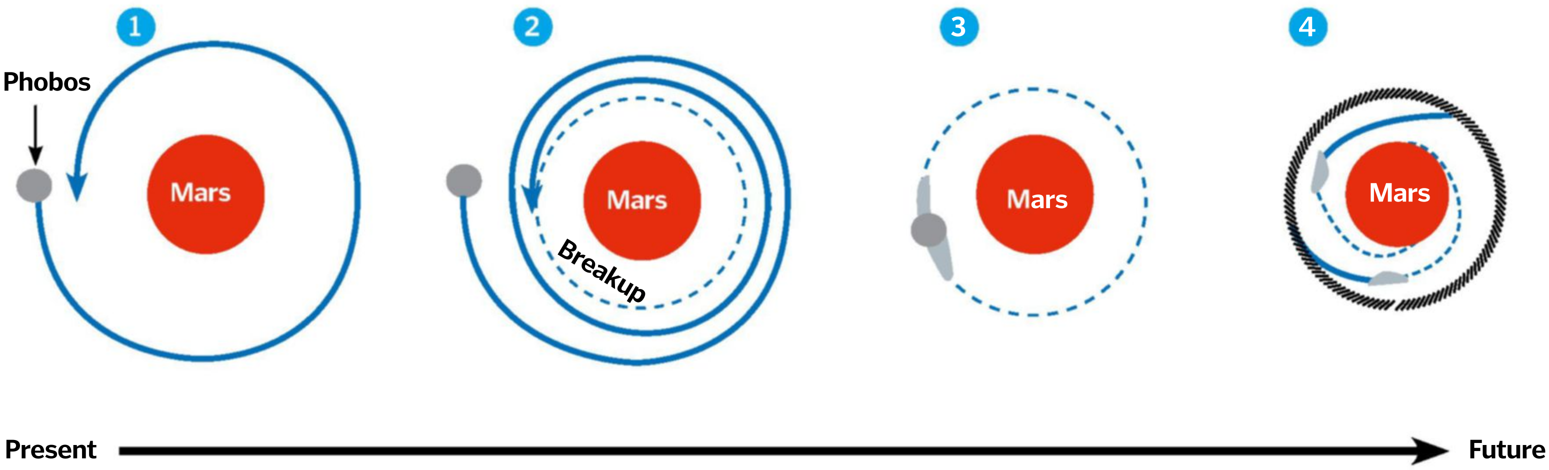
Will Mars get rings?

One of the Red Planet's two moons is on a death spiral towards it

Mars has two moons, Phobos and Deimos, and scientists think the former's days are numbered. In about 10 to 50 million years, Phobos is expected to break apart and possibly form a ring around Mars. Why? Well, Phobos is slowly falling towards the Red Planet due to the gravitational pull of Mars. It orbits just 6,000 kilometres above the surface (in comparison, our Moon is 384,000 kilometres away) and is getting closer to Mars by 1.8 centimetres a year. Eventually, the weakest, most damaged material will be pulled from the moon. Scientists aren't sure if it will then fall towards Mars and impact the surface, or if the fragments will form a ring. Either way, it should be pretty spectacular.

Ring on it

How Phobos might break apart in Martian orbit



1. Orbit
Phobos currently orbits about 6,000 kilometres above Mars, but is falling by 1.8 centimetres every year due to the gravitational force from the Red Planet.

2. Break up
In about 10 million years, Phobos might begin to break up as Mars' gravity pulls it apart. This will depend on if it is rubble-like rather than solid inside.

3. Ring
The moon's dusty outer layer may form a temporary ring around Mars in just a week. Its more solid chunks, however, will likely impact the surface of Mars.

4. Spectacle
Scientists predict Mars may keep this ring for 1 to 100 million years, leaving Deimos – which will not go through a similar process – as the planet's only moon.

The Opportunity rover's adventure

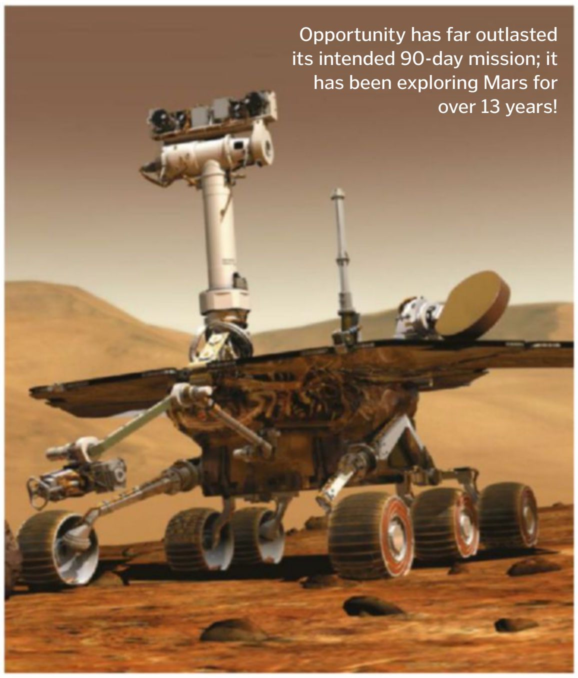
The NASA machine that's explored Mars for more than a decade

When NASA's Opportunity rover landed on Mars on 25 January 2004, our knowledge of the Red Planet was just taking shape. But helped by this 'little rover that could', we've learned more about this world than ever before.

Opportunity was one of the two twin Mars Exploration Rovers – the other being Spirit – that touched down on Mars around the same time. Both were designed to last about 90 days on the surface, but using their solar panels to keep their power running, Spirit lasted until 2010, while Opportunity is still going strong today.

In its time on the surface Opportunity has travelled more than 44 kilometres – longer than the distance of a marathon on Earth – and returned thousands of images. It has studied a number of interesting regions on Mars, including Endurance crater and, most recently, Endeavour crater. Among its many findings, it has discovered strong evidence that Mars has a watery history, and observed dust storms tearing across its surface.

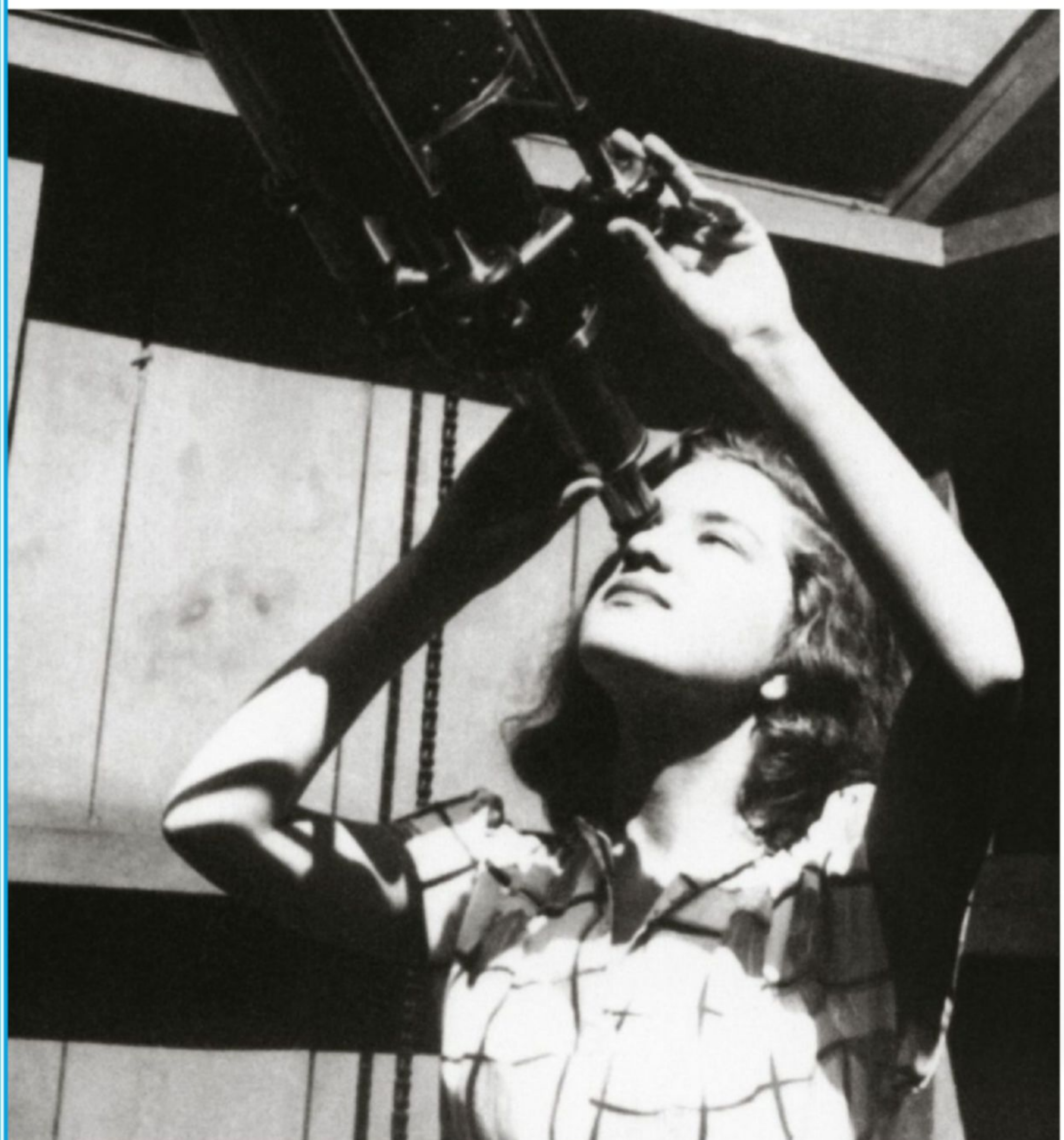
It is now driving down a gully believed to have been carved by water, with plenty more interesting science to come.



Opportunity has far outlasted its intended 90-day mission; it has been exploring Mars for over 13 years!

Vera Rubin

A pioneering scientist whose clinical observations of galaxies helped to shape modern astronomy



As a child, Vera Rubin used to spend her evenings staring up at the stars. She found nothing more interesting than studying the night sky and it was this passion that defined her life and her career.

Unfortunately, in 1940s America, astronomy wasn't considered a viable career for a young woman, and many universities simply didn't allow females to study this branch of science. But Rubin was undeterred and was successfully awarded a scholarship for Vassar College, one of the few institutions that did.

She worked hard, going on to gain a doctorate at Georgetown University, all while raising a family. Despite her success, many males in her profession refused to take her seriously. Her university thesis explained that galaxies were distributed in clusters, rather than being evenly spaced, but many of her peers showed litte interest in these observations.

It was in the 1960s and 70s that she undertook her most notable work. Assisted by fellow astronomer Kent Ford, the two studied the rotation curves of the Andromeda Galaxy. To their surprise, they found evidence of motion that went against the teachings of Newton. Newton's law of universal gravitation states that objects further from a central mass have slower orbits. This is partly why, for instance, Neptune

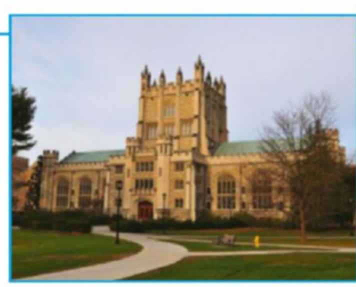
Vera Rubin was fascinated by the stars from a young age and made many startling discoveries about dark matter

A LIFE'S WORK

How Vera Rubin went from child stargazer to trailblazing astronomer

1928
On 23 July, Vera Florence Cooper is born in the city of Philadelphia in the US.

1948
Graduates from Vassar College as the only astronomer in her class and gains a master's degree three years later from Cornell University.



1954
Rubin is awarded a PhD from Georgetown University. Her thesis on the distribution of galaxies paves the way for an incredible career in astronomy.

1965
Becomes the first woman to obtain formal approval to use, and study in, the Palomar Observatory in Southern California.

The big idea

The Rubin-Ford effect and how it changed the study of astronomy

Vera Rubin's discoveries helped shape the modern understanding of galaxies. Contrary to past theories, she observed stars at the edge of the Andromeda Galaxy moving at the same speed as those nearer the centre. Rubin theorised that this should make a galaxy shed its matter, but for some reason they remained stable. She therefore proposed that galaxies were stabilised by an invisible yet dense mass called dark matter. The idea of dark matter was first proposed in the 1930s, but Rubin had provided evidence to suggest that it was abundant in the universe.

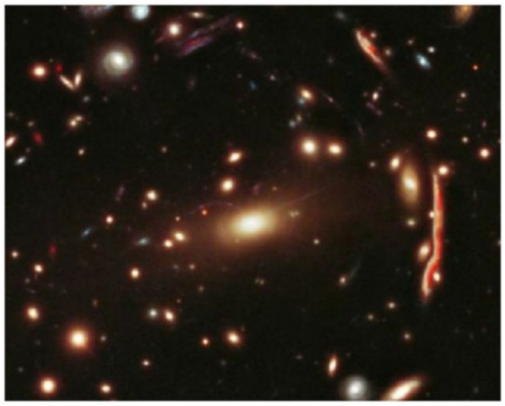
Rubin and Ford studied the Andromeda Galaxy before moving on to other star clusters

takes much longer to orbit the Sun than Mercury. But Rubin observed stars on the edge of Andromeda moving at the same rate as those nearer the centre. She reasoned that this was down to an invisible mass called dark matter.

The idea of dark matter had been suggested a few decades earlier by Swiss astronomer Fritz Zwicky, but Rubin and Ford were the first to provide evidence for its existence. The duo continued to gather data to reinforce their findings and prove that Andromeda wasn't an anomaly. After analysing over 200 galaxies and finding similar results, their theory is now categorically accepted by fellow astronomers.

Rubin also taught at various institutes during her career, including Montgomery College and Georgetown University. She was committed to sharing her knowledge with the next generation of students and was a mentor and an inspiration to young women wanting to study astronomy. All four of her children gained PhDs, and Rubin wanted young female astronomers to not be held back by their gender like she once was.

Vera Rubin received the Royal Astronomical Society's Gold Medal in 1996, the first woman to do so since Caroline Hershel in 1828. She is remembered as a dedicated astronomer whose discoveries were critical to our current understanding of the universe.



Rubin's observations provided evidence for the existence of dark matter, a mysterious particle thought to make up over 80 per cent of the universe

Rubin's work challenged the accepted theories about galactic motion and distribution

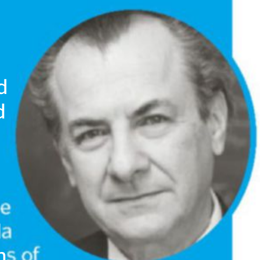
"Rubin was committed to sharing her knowledge with the next generation of students, and was a mentor and an inspiration to young women"

In their footsteps

Sandra Faber

As a student, US astronomer and astrophysicist Sandra Faber worked with Rubin, who advised her on her thesis. Faber is currently a professor emeritus at the University of California at Santa Cruz, and her research focuses on galaxy evolution as well as the structure of the universe itself. She has been involved with Hubble and WM Keck Observatory projects, and in 2013 she was awarded the National Medal of Science by President Barack Obama for her outstanding contributions to science.

Gérard de Vaucouleurs



Gérard de Vaucouleurs and his wife Antoinette worked together on extragalactic observational astronomy. They measured light in galaxies and devised the de Vaucouleurs Law, a formula for the surface illuminations of elliptical galaxies. Rubin's work inspired Gerard to publish his theory of a 'Local Supergalaxy', later renamed as the Local Supercluster, which spans around 100 million light years and encompasses our cosmic neighbourhood. Gérard also studied galaxies in the previously uncharted areas of the Southern Celestial Hemisphere, and mapped parts of Mars for NASA's Mariner 9 mission.

1965
After teaching at Montgomery College and Georgetown University, she joins the Carnegie Institution department of Terrestrial Magnetism.

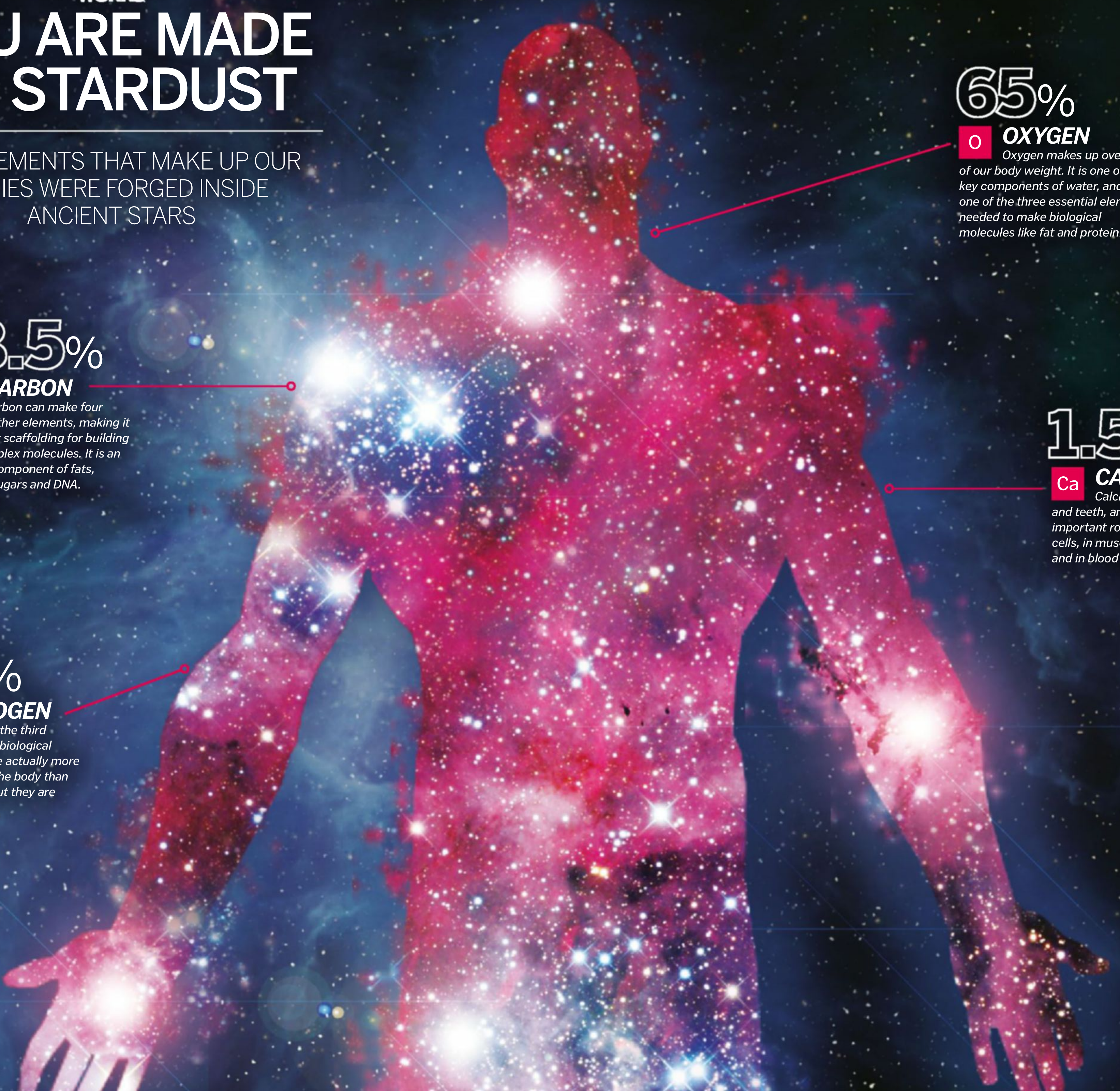
1970s
Provides firm evidence for the existence of dark matter by demonstrating how this invisible mass is responsible for the speed of cosmic dust and the stability of galaxies.

1993
President Bill Clinton presents Rubin with the United State's highest scientific award, the National Medal of Science.

2016
Dies aged 88 in Princeton, New Jersey. She remains one of the most important astronomers of the 20th century.

YOU ARE MADE OF STARDUST

THE ELEMENTS THAT MAKE UP OUR BODIES WERE FORGED INSIDE ANCIENT STARS



65%

O ***OXYGEN***

Oxygen makes up over half of our body weight. It is one of the key components of water, and is one of the three essential elements needed to make biological molecules like fat and protein.

18.5%

C ***CARBON***

Carbon can make four bonds to other elements, making it the perfect scaffolding for building large, complex molecules. It is an essential component of fats, proteins, sugars and DNA.

1.5%

Ca ***CALCIUM***

Calcium is found in bones and teeth, and also plays an important role in signalling between cells, in muscle and nerve function, and in blood clotting.

9.5%

H ***HYDROGEN***

Hydrogen is the third element found in all biological molecules. There are actually more hydrogen atoms in the body than carbon or oxygen, but they are much lighter.

1.1%

P **PHOSPHORUS**

Phosphorus, like calcium, helps to provide strength to bones and teeth. It is also involved in energy use, and is a vital component in DNA, helping to hold the whole structure together.

3.2%

N **NITROGEN**

Oxygen, carbon and hydrogen make up the core of all biological molecules, but lots of other elements are used in smaller amounts. Nitrogen is found in both DNA and protein.

0.2%

S **SULPHUR**

Sulphur is found in some of the building blocks of protein. It can make strong bonds to other sulphur atoms, helping to fix proteins into their 3D shapes.

0.4%

K **POTASSIUM**

Potassium ions are found dissolved inside cells and in body fluids. They carry an electric charge, and are used by nerve cells and muscle cells in the transmission of electrical impulses.

0.2%

Na **SODIUM**

Sodium is another electrolyte that carries charge inside the body. Along with potassium and calcium, it is one of the key elements responsible for normal nerve and muscle function.

THE PERIODIC TABLE OF THE ELEMENTS

■ *INCLUDED IN THE HUMAN BODY*

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	Lu	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Lr	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Uut	Fl	Uup	Lv	Uus	Uuo

La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Tb
Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No

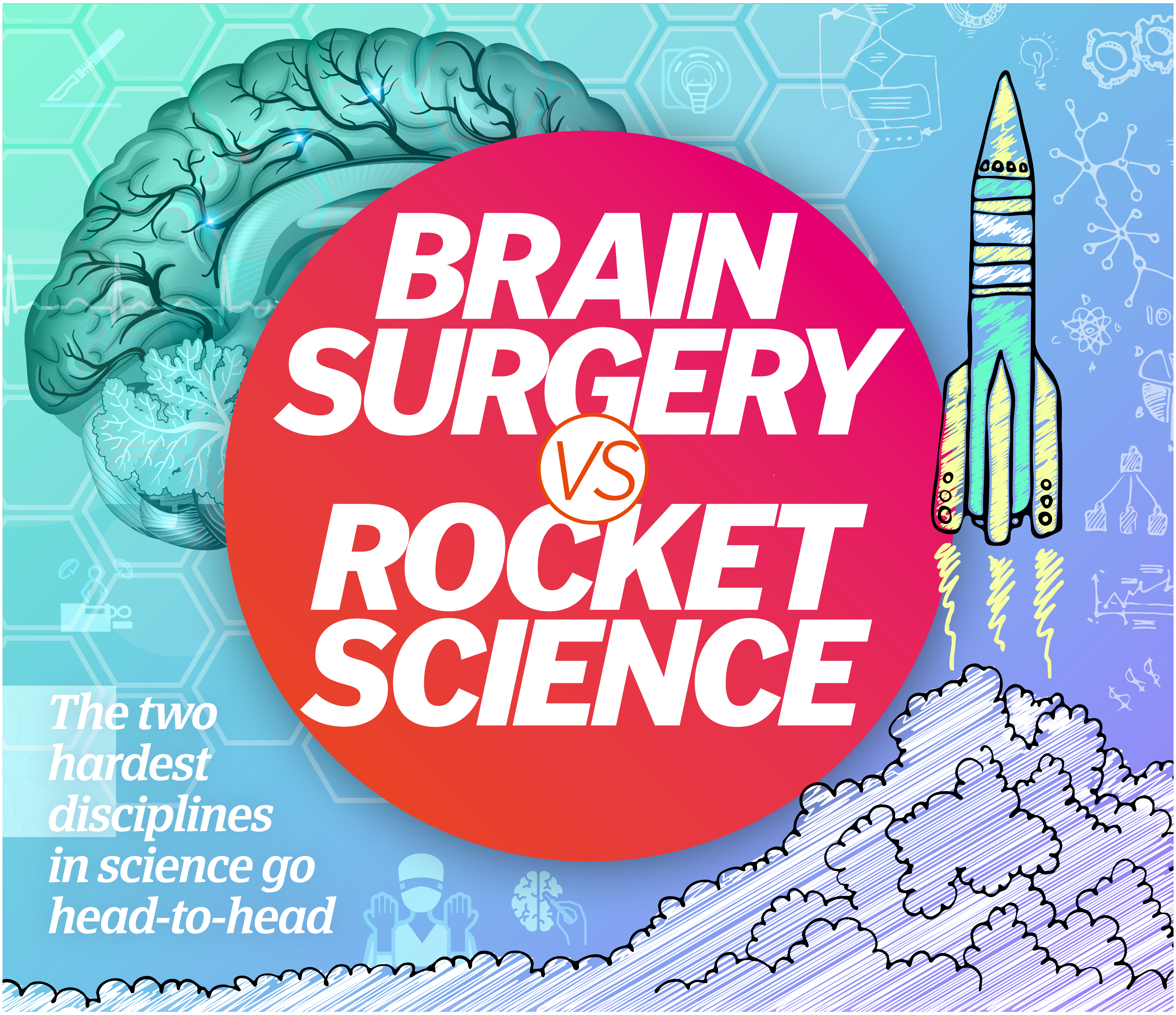
0.4%

Cl Mg Mn Fe F Co

Cu Zn Se Mo I Li Al

AND THE REST

There are many other trace elements in the human body, including chlorine, magnesium, manganese, iron, fluorine, cobalt, copper, zinc, selenium, molybdenum, iodine, lithium, and aluminium.



BRAIN SURGERY VS ROCKET SCIENCE

The two hardest disciplines in science go head-to-head

Both brain surgery and rocket science have reputations for being some of the hardest intellectual fields of work, and those reputations are well earned. The former works with the most complex structure known to man, while the latter wrangles with physics and chemistry to enable the exploration of space.

It's hard to compare the two disciplines directly. Rocket scientists work in the design, development and testing of rocket engines and the vehicles that they propel, whether these be spacecraft, missiles or even jetpacks. Brain surgeons, on the other hand, apply knowledge of neuroscience and anatomy to fix brains that have gone wrong. Rocket scientists do research and development, and their findings allow engineers and mechanics to build and use the big, impressive rockets that carry astronauts to the Moon. Brain surgeons use the science of neuroscientists and tools developed by engineers and physicists to work at the front line of medicine.

A fairer comparison would be rocket scientists versus neuroscientists, or brain surgeons against rocket mechanics, but for the sake of argument, we're going to put this to one side and compare them anyway.

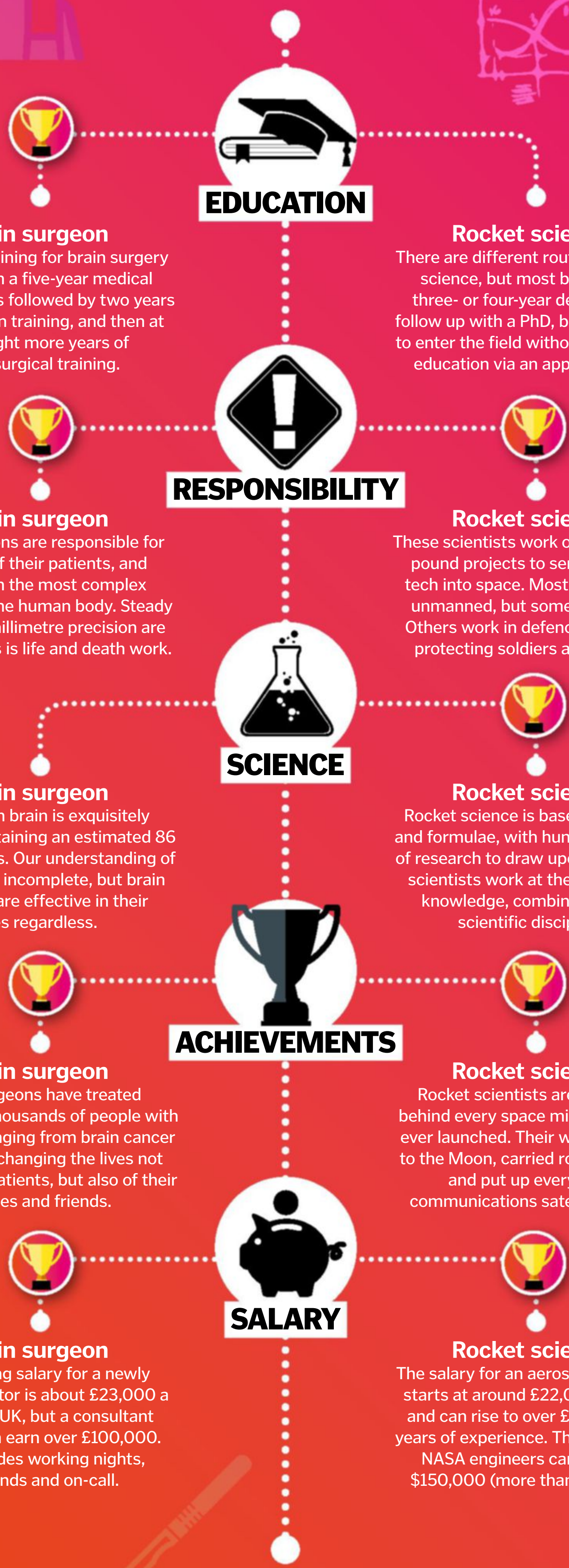
Both fields are relatively new, and are growing in depth and scale all the time as advancements are made. Modern rocket science began in the early 20th century, advanced substantially during World War II with the advent of guided missiles, and leapt out of this world during the space race between the Soviet Union and the United States that began in the 1950s.

Modern brain surgery started at a similar time and has jumped rapidly from crude operations using imprecise tools to precision interventions that take advantage of the latest in biomedical tech. Read on to find out if one really is harder than the other.

> "Both fields are relatively new, and are growing in depth and scale all the time"

Let the battle of the brains begin

It's time to discover the routes and rewards available to these scientists



EDUCATION

Brain surgeon
In the UK, training for brain surgery begins with a five-year medical degree. This is followed by two years of foundation training, and then at least eight more years of neurosurgical training.

Rocket scientist
There are different routes into rocket science, but most begin with a three- or four-year degree. Some follow up with a PhD, but it's possible to enter the field without a university education via an apprenticeship.

RESPONSIBILITY

Brain surgeon
Brain surgeons are responsible for the lives of their patients, and operate on the most complex structure in the human body. Steady hands and millimetre precision are required. This is life and death work.

Rocket scientist
These scientists work on multimillion-pound projects to send the latest tech into space. Most missions are unmanned, but some carry crew. Others work in defence, critical for protecting soldiers and civilians.

SCIENCE

Brain surgeon
The human brain is exquisitely complex, containing an estimated 86 billion neurons. Our understanding of its biology is incomplete, but brain surgeons are effective in their roles regardless.

Rocket scientist
Rocket science is based on physics and formulae, with hundreds of years of research to draw upon. But, rocket scientists work at the edge of this knowledge, combining several scientific disciplines.

ACHIEVEMENTS

Brain surgeon
Brain surgeons have treated hundreds of thousands of people with conditions ranging from brain cancer to epilepsy, changing the lives not only of their patients, but also of their families and friends.

Rocket scientist
Rocket scientists are the brains behind every space mission that has ever launched. Their work took men to the Moon, carried rovers to Mars, and put up every single communications satellite in orbit.

SALARY

Brain surgeon
The starting salary for a newly qualified doctor is about £23,000 a year in the UK, but a consultant surgeon can earn over £100,000. This includes working nights, weekends and on-call.

Rocket scientist
The salary for an aerospace engineer starts at around £22,000 in the UK and can rise to over £60,000 with years of experience. The highest paid NASA engineers can earn over $150,000 (more than £120,000).

The defector

Few people can claim to have worked as both a doctor and a rocket scientist, but Hermann Oberth did just that. He was one of the first people ever to work on rocket science, and is hailed by NASA as one of the fathers of rocketry. But before that he was a World War I medic.

His fascination with science began in his early teens, reading Jules Verne science fiction adventure novels while he recovered from scarlet fever. When he returned from the war, he retrained as a physicist and mathematician and started to design rockets. His dream was to escape Earth's gravity, and his books about travel in space, published in the 1920s, cover everything from multi-stage rockets to Moon landings and space stations.

His medical background, combined with a bit of self-experimentation, convinced him that humans could survive a journey out of this world, and after much theorising, his rocket finally launched for real in 1931.

Hermann Oberth (front) and his team were early pioneers of rocket science

Operating while patients are conscious allows surgeons to identify functional areas of the brain that must be avoided

Advanced surgical tools

In brain surgery, the tiniest movements make a difference, so surgeons are turning to robots for help. Endoscopes are already used to perform precision surgery with minimal disruption to surrounding tissue, but tech in development aims to take this even further. Robots are better than human hands when it comes to holding cameras steady, and with their help, laser microscopes should be able to capture high-resolution images inside the brain. Tumour paint is also in development to light up cancer cells. It sticks only to the affected cells, avoiding healthy tissue, and should help to guide surgeons to the parts of the brain that need to be removed.

Live images enable surgeons to work with pinpoint accuracy

BRAIN SURGERY

Brain surgeons operate on the most complex structure known to humans

Neurosurgeons are responsible for the treatment of disorders of the brain and spinal cord. It's an area of medicine that has evolved from crude practices like lobotomy to intricate operations performed under microscopes with the assistance of robots.

The field is notoriously complex, and many surgeons choose to specialise in a particular area, including neuro-oncology (tumours), paediatric neurosurgery (babies and children), functional neurosurgery (chronic diseases like epilepsy), neurovascular surgery (aneurysms and blood vessel disorders), or traumatology (head injuries). And surgery only makes up a part of a brain surgeon's week.

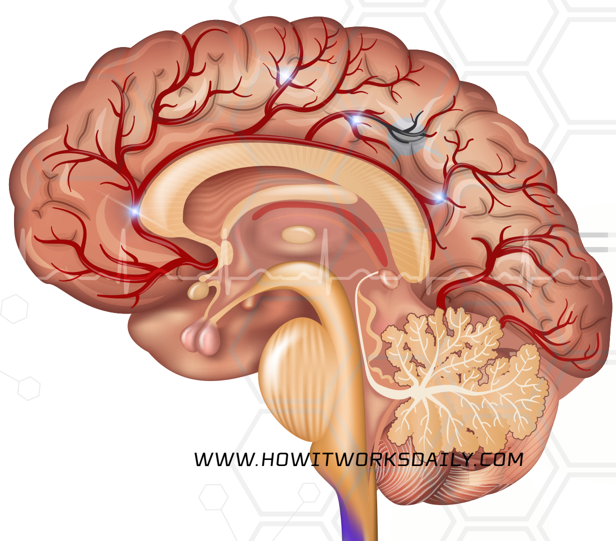
They can spend a couple of days in theatre, but the remainder of the time is often spent working with patients outside of the operating room. They attend clinics to diagnose and monitor, and conduct ward rounds to follow up on their patients after they've been operated on.

Many operations typically involve removing a section of the skull and stapling it back into place but, as the field advances, surgeons are working with smaller and smaller incisions. A combination of scans and microscopes help the team to find the correct location during surgery by magnifying brain tissue and revealing areas of damage invisible to the naked eye. And, if the area can't be accessed easily, flexible cameras called endoscopes can be used. These are equipped with surgical tools, allowing surgeons to get at hard-to-reach areas with minimal disruption.

Endoscopes are generally used for surgery at the base of the brain, and the camera is threaded through a coin-sized hole in the skull, or through the mouth or nose. Scans guide the probe, and robotics can be used to steady the camera as biopsies are taken or tumours are carefully removed.

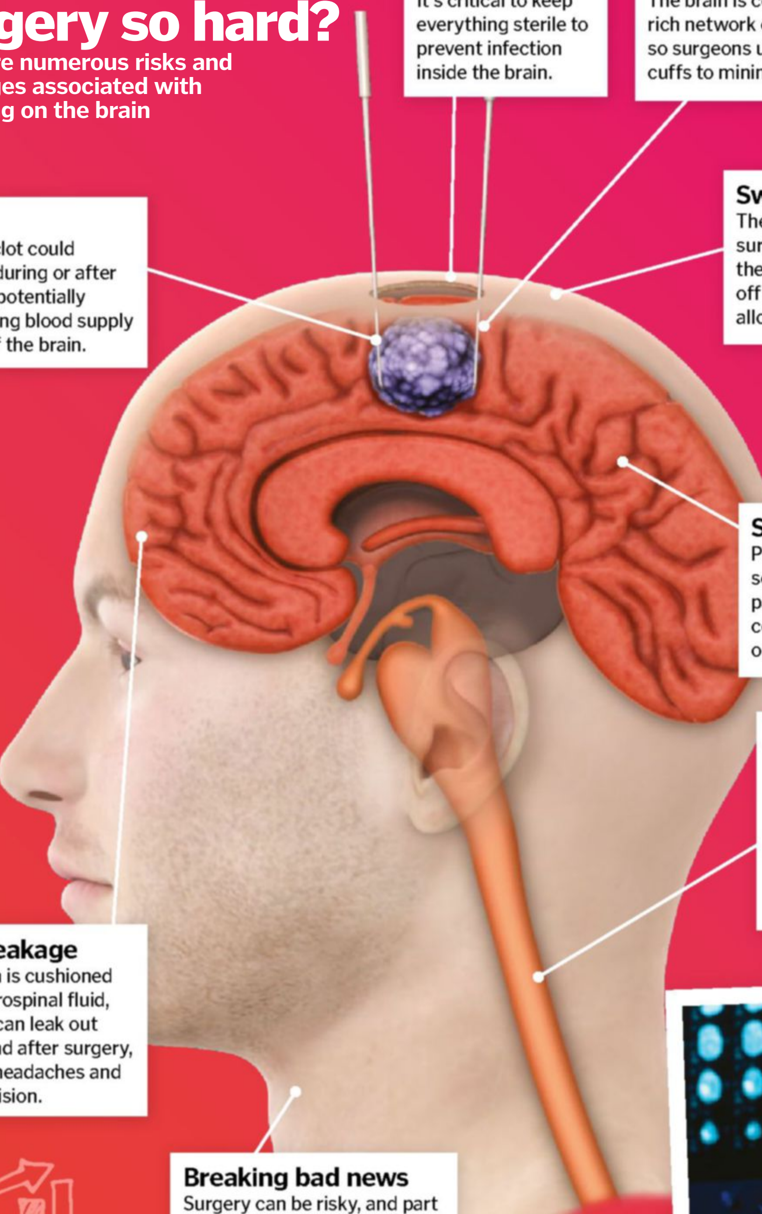
Another option is noninvasive surgery, with a tool called a gamma knife replacing the typical stainless steel scalpels. This process involves the use of beams of gamma radiation to deliver high doses of radiotherapy to specified areas of the brain while sparing as much of the surrounding healthy tissue as possible.

As technology advances, simulation is set to become an invaluable tool in a brain surgeon's arsenal. Computer models will allow doctors of the future to predict the effects of surgery before they do it, taking into account the impact different cuts would have on healing time and side effects. Virtual or augmented reality systems could one day allow surgeons to step inside 3D maps of their patients' brains before, and even during, surgery.



What makes brain surgery so hard?

There are numerous risks and challenges associated with operating on the brain



Infection
It's critical to keep everything sterile to prevent infection inside the brain.

Bleeding
The brain is covered with a rich network of blood vessels, so surgeons use clamps and cuffs to minimise bleeding.

Clots
A blood clot could develop during or after surgery, potentially obstructing blood supply to part of the brain.

Swelling
The brain can swell after surgery, and sometimes the flap of bone is left off for a few days to allow it to subside.

Seizures
Patients can experience seizures during surgery, particularly if they are conscious while the operation is taking place.

Collateral damage
Surgeons work within millimetre margins, but surgery can cause damage to senses, speech, memory and muscle control.

Fluid leakage
The brain is cushioned by cerebrospinal fluid, and this can leak out during and after surgery, causing headaches and blurred vision.

Breaking bad news
Surgery can be risky, and part of a brain surgeon's job is to inform family members when operations don't go well.

HEROES OF BRAIN SURGERY

Harvey Williams Cushing
Cushing pioneered delicate surgical techniques and performed over 2,000 operations. He gathered samples from every case and created a vast registry, complete with patient notes and photos.

Sir William Macewen
Macewen produced the *Atlas Of Head Sections*, a book that mapped the brain with images of real specimens. He was able to pinpoint damaged areas just by watching for the muscles and senses affected.

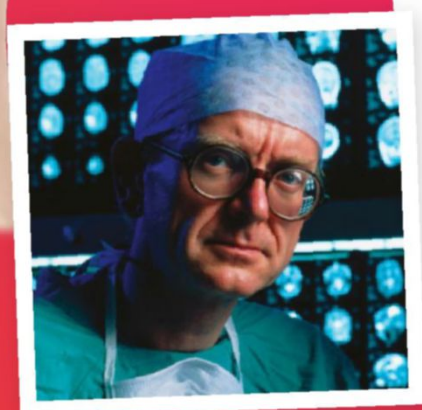
Wilder Penfield
Penfield pioneered 'awake surgery' for patients with epilepsy, keeping them conscious when mapping the areas of the brain responsible for different functions, including speech and memory.

Pioneering practice

Major surgery is most often performed under general anaesthetic, but operating on the brain is a bit different. Keeping patients awake through the procedure can help to protect critical parts of the brain from damage.

At the start of the procedure, the patient is often put to sleep under sedation, allowing a section of the skull to be removed. They are then woken up again. The brain itself doesn't feel any pain, and the scalp is numbed using local anaesthetic.

Using electrical probes, the surgeons stimulate different parts of the brain while the patient reads, talks or even plays an instrument. If there's any change, the surgeons know to avoid that particular area.



Surgeon Henry Marsh (left) specialises in awake craniotomy procedures, operating on his patients under local anaesthetic

Evolution of brain surgery

Ancient bones suggest brain surgery has a long history

5,000 BCE
Archaeological evidence suggests that the first surgery ever performed was brain surgery. Trepanation involved making a hole in the skull, thought to release spirits and relieve headaches.

1879
In this year, William Macewen removed a brain tumour from a patient for the first time. The woman is thought to have had a slow-growing, noncancerous growth called a meningioma.

1928
Wilder Penfield began developing the techniques for awake craniotomy, using local anaesthetic to perform brain surgery while patients were conscious, to help avoid damaging functional areas.

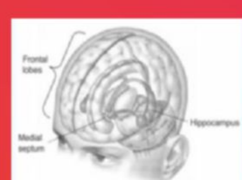
1935
The first lobotomy was performed in an attempt to treat mental illness, disrupting connections in the frontal lobes. The practice stopped when drug treatments became available in the 1950s.

1953
A patient known as HM underwent radical surgery to cure his epilepsy, and ended up with severe memory problems. His case was followed for 50 years, revealing a lot about memory.

2017
The first ever human head transplant is set to be attempted by Italian surgeon Professor Sergio Canavero on a terminally ill man. He will use a specially developed knife that cuts with micrometre accuracy.







ROCKET SCIENCE

Rocket scientists design, develop and test rocket engines for use in space and defence

Rockets bring space within reach

In 1957, the Soviet Union put the first satellite into orbit around the Earth. Known as Sputnik 1, the little metal sphere was the first milestone in a furious race to conquer space.

Four years later, in 1961, Yuri Gagarin became the first person in space. Four years after that, NASA's Mariner 4 visited Mars. After another four years, two people set foot on the Moon in 1969. The pace of progress in this field was astounding, and everything that left the atmosphere did so under rocket power.

By 1971 the Salyut 1 space station was launched, allowing people to remain in orbit around the Earth for weeks at a time. Several others followed, including the legendary Mir, which spent 15 years in service. It was replaced by the International Space Station, a partnership effort between the world's leading space agencies. People have been onboard it continuously since 2000.

Rocket engines also started the two Voyager spacecraft on their journey out of the Solar System in the late 1970s. Both are now further away than Pluto, and Voyager 1 is now in interstellar space. They have sent rovers to Mars, landers to asteroids, and they've launched over 2,000 satellites into Earth-orbit. None of this would have been possible without rocket scientists, and the best is yet to come.

The maiden voyage of NASA's Space Shuttle Columbia in 1981

When people think of rocket science, they most often think of space, but the field deals with the physics and engineering of anything powered by rocket engines. This includes missiles, aircraft, spacecraft and, technically, fireworks.

Some of the very earliest rockets were tubes filled with cakes of gunpowder – used by the Chinese as weapons as early as 1232. The powder contains carbon (the fuel), potassium nitrite (the oxidiser) and a bit of sulphur, which helps to get the reaction going. As the gunpowder burns it creates gas, which shoots out of the back of the tube as exhaust. This exhaust propels the rocket forwards. Adding metal oxides to the mix creates colourful firework displays.

Modern rocketry is based on the same principles, but it didn't really get started until the early 1900s. Rockets contain fuel and an oxidiser and work by funnelling exhaust gas through a nozzle. The nozzle is designed to let the gas expand and cool before it escapes, allowing more energy to be extracted by the engine. The earliest rockets were based on solid fuel, and these are still used to provide powerful, consistent thrust, but the power output can't be controlled or switched off. Newer liquid fuel engines get around this problem, but come with complicated pipe systems and the fuel is heavy and therefore a lot more expensive.

> "Some of the very earliest rockets were tubes filled with cakes of gunpowder"

A rocket scientist's job focuses on using expertise across the scientific disciplines to find a balance. Whether it's working out the right combination of rocket stages required to lift a satellite, or developing a new nozzle from lighter materials that can still handle intense heat, they develop, test and refine rocket engines to make them cheaper, safer, lighter, more powerful and more efficient.

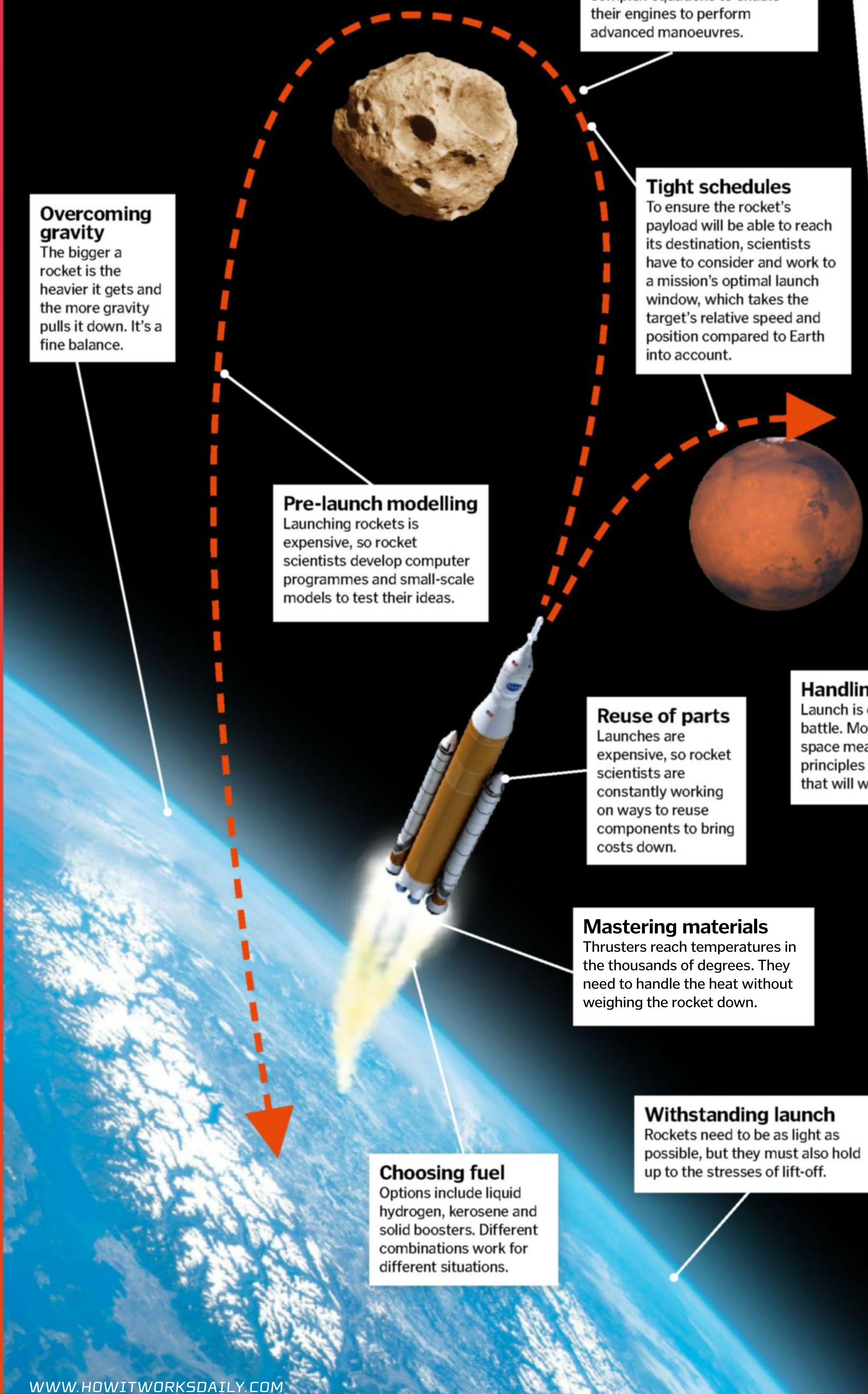
To do this, they not only need to understand the chemistry of the propellants; they also need knowledge of engineering, aerodynamics, and the physics of flight. And, with test launches of new technology being expensive and dangerous, much of the development work involves small-scale models and computer simulations. This allows researchers to run multiple tests, tweaking lots of different conditions to come up with the optimal solution before it's ever tested in reality, but it adds an extra layer of complexity to the job.

Advances in rocket engines are going to be crucial as space exploration projects become ever more complex and ambitious, and rocket scientists are the people who are going to make it all happen.

SpaceX's Falcon 9 reusable booster required pioneering rocket science to build

What makes rocket science so hard?

This field has a reputation for being challenging, and here's why



Advanced mathematics
Rocket scientists need to master complex equations to enable their engines to perform advanced manoeuvres.

Overcoming gravity
The bigger a rocket is the heavier it gets and the more gravity pulls it down. It's a fine balance.

Tight schedules
To ensure the rocket's payload will be able to reach its destination, scientists have to consider and work to a mission's optimal launch window, which takes the target's relative speed and position compared to Earth into account.

Pre-launch modelling
Launching rockets is expensive, so rocket scientists develop computer programmes and small-scale models to test their ideas.

Reuse of parts
Launches are expensive, so rocket scientists are constantly working on ways to reuse components to bring costs down.

Handling vacuums
Launch is only half the battle. Moving craft in space means using principles and equipment that will work in a vacuum.

Mastering materials
Thrusters reach temperatures in the thousands of degrees. They need to handle the heat without weighing the rocket down.

Withstanding launch
Rockets need to be as light as possible, but they must also hold up to the stresses of lift-off.

Choosing fuel
Options include liquid hydrogen, kerosene and solid boosters. Different combinations work for different situations.

HEROES OF ROCKET SCIENCE

Konstantin Tsiolkovsky
Tsiolkovsky is one of the fathers of rocketry. He published an equation in 1903 explaining the link between a rocket's mass, its speed and the speed of the propellant. It still forms the basis of rocket physics.

Robert Goddard
Goddard made and tested the first liquid fuel rocket in 1926. His ideas revealed the potential for missile and space rocket technology, and his mathematics and testing helped to make them a reality.

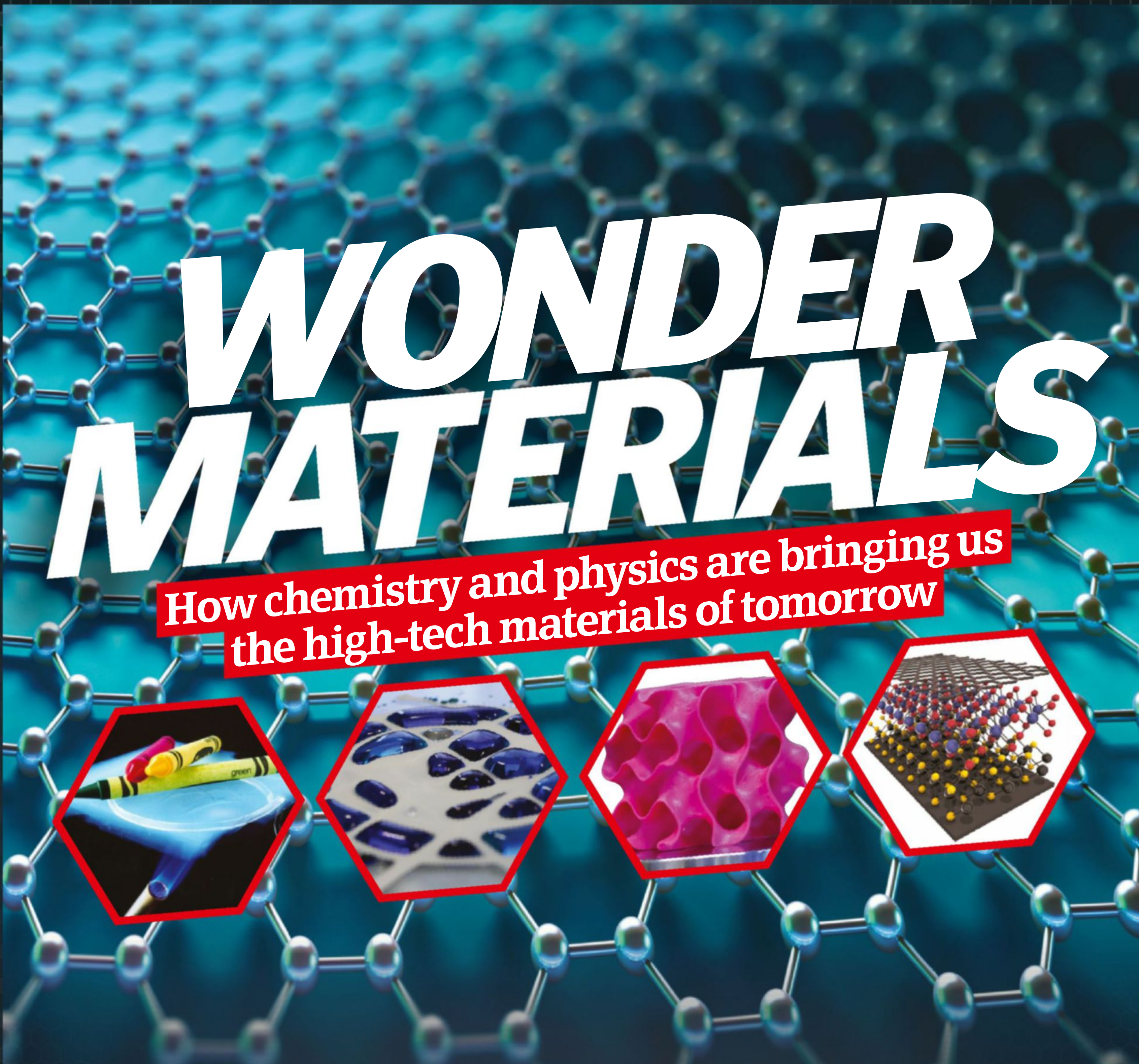
Wernher von Braun
Von Braun led the team that developed the German V-2 missile during World War II. After the war, he moved to the US and became chief architect of the Saturn V rocket used for the Apollo missions.

The verdict?

There's no doubt that both rocket science and brain surgery require some serious thinking power, but it's perhaps unfair that they're singled out as the toughest disciplines in science and medicine. The truth is, none of the achievements made would have been possible without biologists, chemists, physicists, mathematicians and engineers working in other fields.

Rocket scientists build upon decades of scientific enquiry to push the boundaries of human knowledge and develop the technology of tomorrow, while brain surgeons also put research to good use, applying it in the treatment of their patients, often saving lives.

It's safe to say that both are tackling enormous mental challenges, and their work is only going to become more complicated as time goes on.



WONDER MATERIALS

How chemistry and physics are bringing us the high-tech materials of tomorrow

In the grand scheme of things it's really not too long ago that buildings were made from brick or stone and just about everything else was made from wood or metal. Things changed in 1907 with the development of Bakelite, the first synthetic plastic, although it would take until the 1940s and 1950s before plastics really started to take off. Initially thought of as a cheap alternative to quality materials, plastic – or polymers to give them their technical name – soon became the material of choice in a wide range of areas.

Interest in polymers can be thought of as the birth of materials science, a discipline encompassing chemistry, physics and engineering with the aim of providing the materials needed for modern industry. This truly is all encompassing. For example, the semiconductor materials that are used in microchips and found in all our electronic devices are the result of research into materials science, but this is just the tip of the iceberg. Today's scientists are examining structural, electrical, electronic, optical and biocompatible materials ranging from metallic alloys through to ceramics, to bizarre sounding substances such as conducting plastics and metallic foams.

One of the most hyped areas of materials science concerns new allotropes of carbon. At one time carbon was thought to exist in two forms – graphite and diamond. Then, in 1985, a new allotrope called buckminsterfullerene was discovered and other new forms soon followed. Graphene, one of these new forms of carbon, is just one of the amazing substances we'll discover as we start our investigations.

AEROGELS

A material so light that 150 bricks would weigh only as much as a gallon of water

Gels are well known but, perhaps, not fully appreciated. The jelly in a trifle, for example, appears fairly solid yet can be almost entirely composed of water. The remaining fraction is made from gelatine, which creates a molecular cage-like structure, trapping the water and providing stability.

Aerogels are similar except, instead of a liquid, it's a gas – often air – that makes up the majority of their volume. Most aerogels contain at least 95 per cent gas, although they have been produced with as much as 99.98 per cent air by volume. Yet that very small percentage of solid is enough to give it solid properties. Aerogels are commonly said to feel like expanded polystyrene, even though they are much lighter. Their appearance can be very different, though. Often translucent, aerogels have been referred to as solid smoke.

Most commonly, aerogels are made from silica (silicon dioxide) but they can also be made from other metal oxides, carbon, polymers and even graphene, which can be used to create an aerogel seven times lighter than air. By selecting an appropriate material, the properties of the aerogel can be tailored to a variety of different applications. For example, aerogels made from metal chalcogenides have semiconductor properties, and have potential for energy applications including solar cells and the extraction of hydrogen from water using sunlight.

Being made mostly of air, aerogels are among the lightest of all the solid materials

SMOOTH INSULATOR

- LIGHTWEIGHT
- GOOD THERMAL INSULATOR
- HIGH SURFACE AREA
- GOOD ACOUSTIC INSULATOR

This amazing feat is possible thanks to the aerogel's thermal insulation properties

> "Aerogels have been produced with as much as 99.98 per cent air"

METALLIC HYDROGEN

Researchers at Harvard squeezed solid hydrogen to incredibly high pressures in a diamond anvil

We all know that hydrogen is a gas, but researchers at Harvard University have discovered a different side to nature's most abundant element. By compressing it between diamond tips to ever-increasing pressures, gaseous hydrogen first becomes a transparent solid and then an opaque black solid. However, at a pressure of 495 gigapascals, greater than that at the Earth's core, it becomes shiny and electrically conductive – the hallmark of a metal.

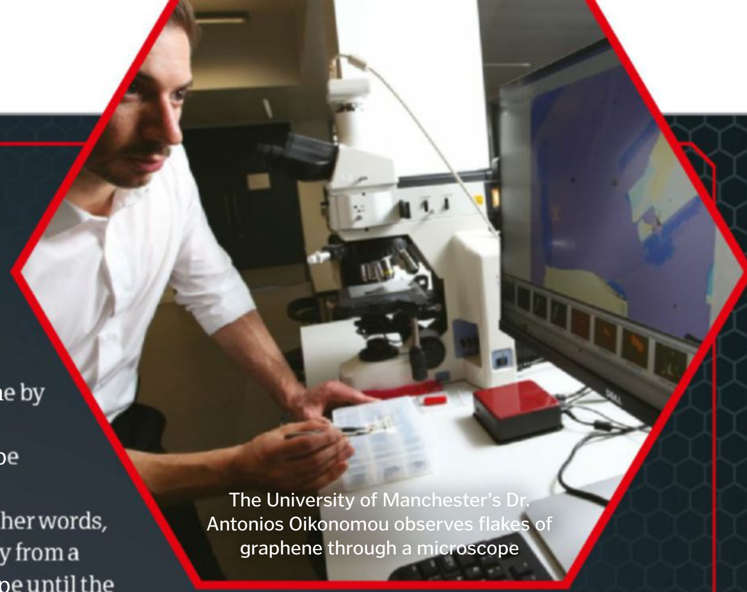
In one sense, this isn't too unexpected, even though the engineering challenges were extreme. After all, in its usual form, hydrogen is the only non-metallic element in Group 1 of the periodic table and the existence of metallic hydrogen was predicted as long ago as 1935. Researchers believe that metallic hydrogen could be a room temperature superconductor that may lead to more efficient electricity transmission. It also holds the promise of a high density rocket fuel, offering benefits in astronautics.

METAL MAGIC

- SOLID AND SHINY
- ROOM TEMPERATURE SUPERCONDUCTOR
- POTENTIAL ROCKET FUEL

GRAPHENE

Move over graphite and diamonds – this new form of carbon has some remarkable properties


The University of Manchester's Dr. Antonios Oikonomou observes flakes of graphene through a microscope

Graphene has been described as the world's first two-dimensional material, and with some justification. For many years carbon was thought to exist as just two allotropes, graphite and diamond. Allotropes are different forms adopted by an element and they can often have different properties, graphite being soft and black, diamond hard and transparent. Both, however, contain carbon atoms bonded together in three dimensions. Graphene, on the other hand, contains carbon atoms in a single plane, bonded to each other in a hexagonal arrangement. As we might expect from the dramatic differences between graphite and diamond, graphene also has its own unique properties, as we'll see later.

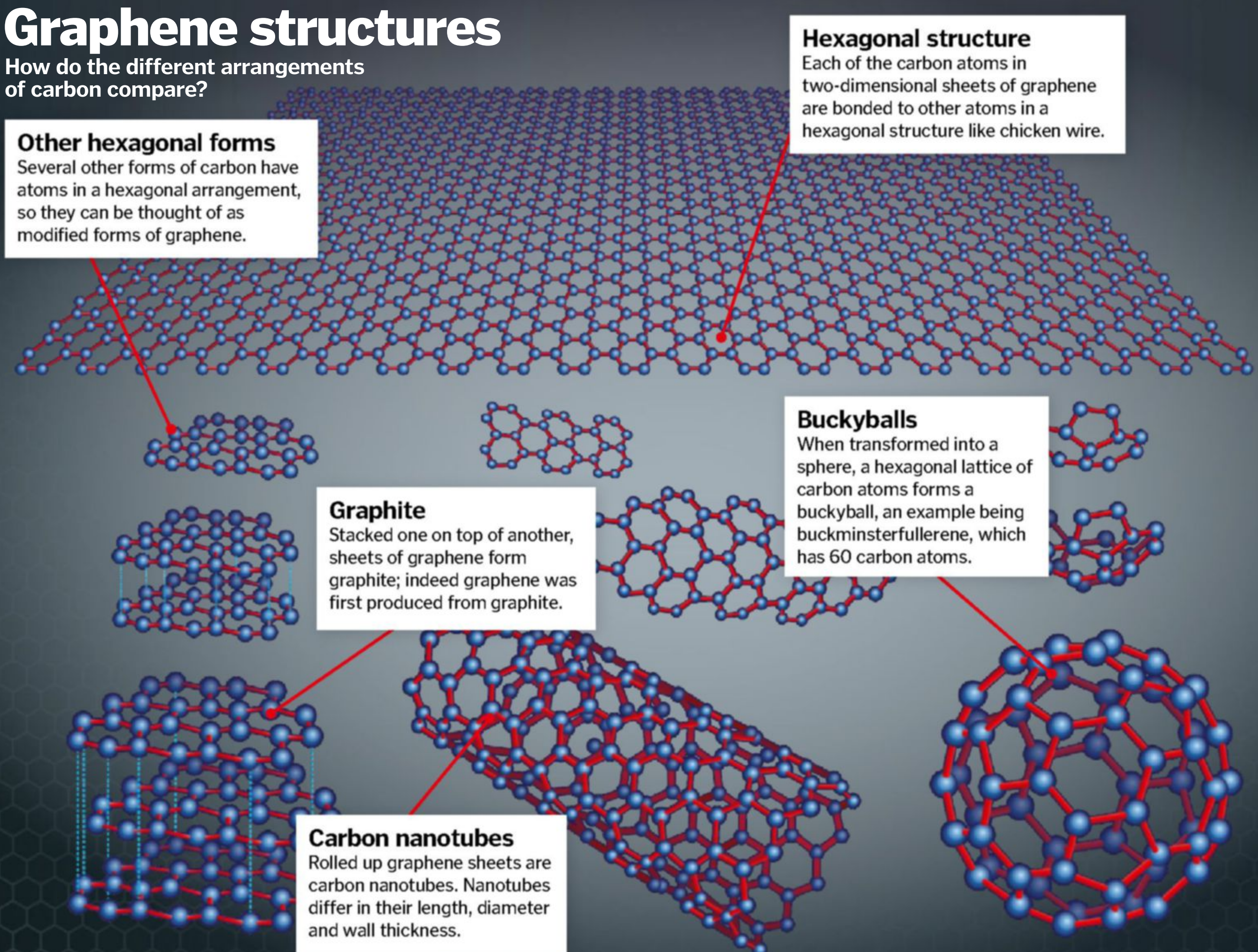
Although graphite is a three-dimensional molecule, it's long been recognised that it's composed of sheets of tightly bonded carbon atoms with much weaker bonds between these sheets. This led to speculation that a two-dimensional form of carbon could exist. Speculation became reality in 2004 when researchers first produced graphene by what sounds like a very low-tech method. Nicknamed the Scotch Tape Method, the technique involved micromechanical cleavage or, in other words, pulling layers of carbon atoms away from a block of graphite using adhesive tape until the layer was just one atom thick.

Graphene can now be produced using various methods that are more appropriate for large-scale manufacturing. A common method is chemical vapour deposition, in which carbon is deposited onto a flat surface as a result of a chemical reaction involving a carbon compound in gaseous form. However, removing the graphene layer from the surface it forms on can be challenging, as can the production of large sheets, especially with no defects. Graphene still can't be considered a commodity material, but it can now be produced in gram rather than milligram quantities so perhaps real-world applications aren't too far away. This is certainly the hope and expectation of the University of Manchester who, in 2016, launched a company to set up a number of spin-off businesses to commercialise the University's pioneering graphene research.

Graphene might have been the first ever two-dimensional material but it wasn't the last. Two-dimensional allotropes of germanium (germanene), silicon (silicene) and phosphorous (phosphorene) have been produced, and several others have been predicted. Unusual and valuable properties, very different from those of the three-dimensional equivalents, have either been demonstrated or are expected.

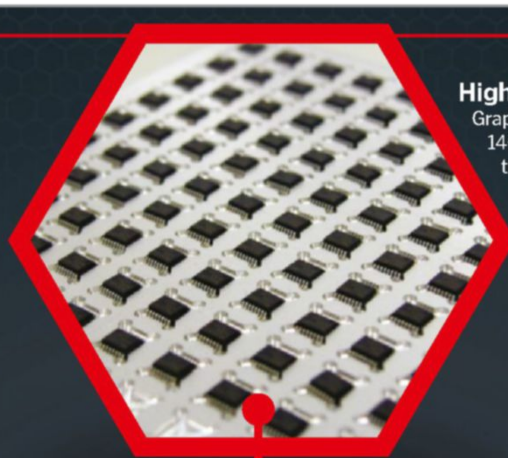
Graphene structures

How do the different arrangements of carbon compare?



POTENTIAL GRAPHENE APPLICATIONS

Here are just some of the many ways that graphene could be used in the not so distant future



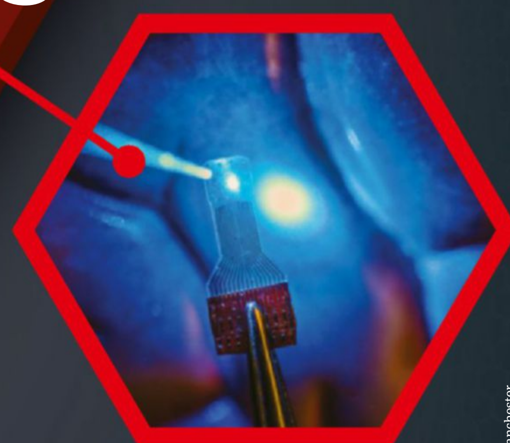
High speed chips
Graphene has an electron mobility 140-times greater than that of silicon. As the speed at which electrons move through a solid in response to an electric field, this could give rise to superfast computing.

Printable electronics
Graphene is an excellent conductor, allowing thin, foldable circuits to be printed onto flexible materials. Applications include rollable solar panels and even intelligent product packaging.

Energy applications
Research suggests several energy-related applications. For example, it could play a key role in the constant quest for batteries that hold more energy and charge more quickly.

Coatings
The properties of materials can be modified using graphene as a coating. It is super-hydrophobic, giving rise to water-repellent materials. It is also the thinnest anticorrosion coating.

"Graphene was been described as the world's first two-dimensional material"

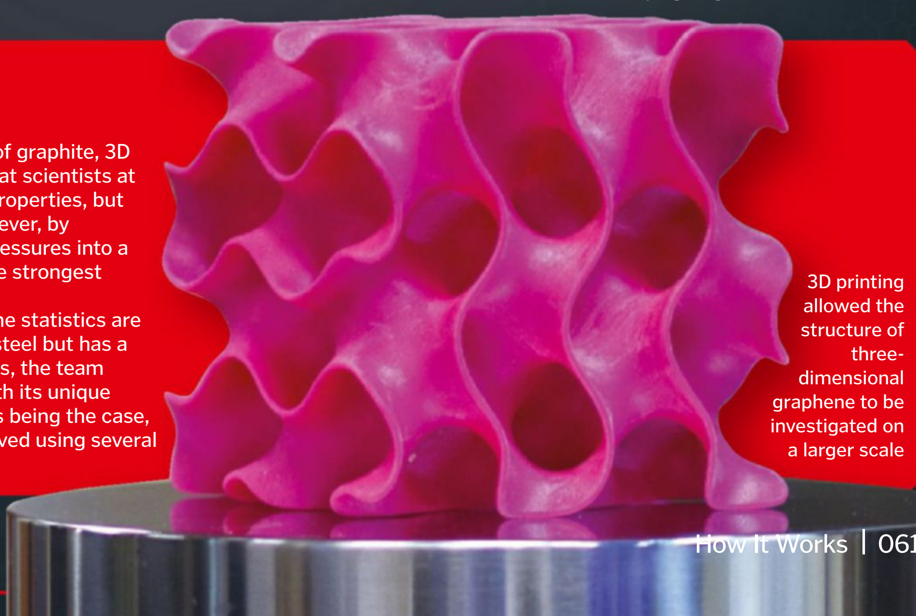


Sensors
Graphene shows considerable potential for biological and chemical sensors. Scientists envisage a wide-range of applications for graphene sensors, from detecting bacteria on teeth to helping diagnose diseases.

3D GRAPHENE

Since graphene has been described as a two-dimensional form of graphite, 3D graphene might sound a strange concept, but that is exactly what scientists at MIT have produced. Certainly, graphene has some remarkable properties, but because it's so thin it isn't suitable as a structural material. However, by compressing flakes of graphene using high temperatures and pressures into a three-dimensional structure, scientists have produced one of the strongest lightweight materials.

While the 3D variant isn't as strong as regular 2D graphene, the statistics are pretty impressive. The new material is ten-times stronger than steel but has a density of just five per cent that of the alloy. Surprisingly perhaps, the team believe that the strength of this new material has more to do with its unique geometrical configuration than the graphene material itself. This being the case, they expect that similar high-strength properties could be achieved using several other raw materials.



3D printing allowed the structure of three-dimensional graphene to be investigated on a larger scale

SELF-HEALING MATERIALS

Amazing substances that can repair themselves just like human skin

It's said that nothing lasts forever, and this is true of the plastics that are used to manufacture many of the products on which we rely. Damage due to fatigue and environmental conditions give rise to microscopic cracks that weaken the plastics, causing them to become less able to survive the rigours of everyday life. As a result, commodities have a limited lifetime, or in the case of expensive commodities, require regular inspection and repair. Self-healing materials are designed to effect repairs when necessary, and there are several ways this can be achieved.

Intrinsic methods of self-repair don't work at the level of the damaging micro cracks, but at the much smaller molecular level. Since that damage is often caused by chemical changes to the plastic, it's clear that if the chemical reaction is reversed, the damage could also be reversed. Intrinsically repairable plastics are designed so that the reactions that cause them to degrade are reversible. Unlike the extrinsic methods we'll see later, however, some manual intervention is required to initiate that chemical reaction, perhaps heating up the material to start the process.

Extrinsic methods are quite different and there are several ways in which cracks can be repaired with no human interaction whatsoever. There are numerous ways in which this can be achieved, as illustrated in the images below, but one thing is common to all. The micro cracks that threaten the wellbeing of the plastic result in the release of chemicals that react to produce new plastic and, in so doing, fill those damaging fissures.

> "REVERSING CHEMICAL REACTIONS CAN ALSO REVERSE THE DAMAGE"

PERPETUAL HEALING

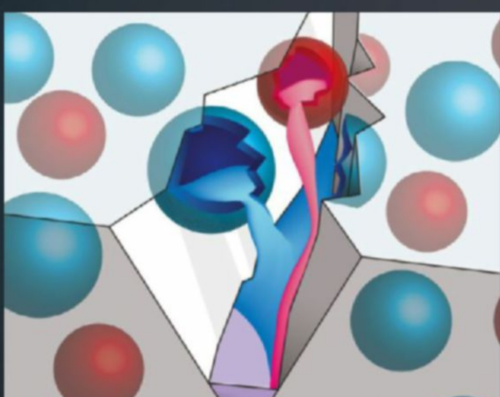
LONG-LASTING

DURABLE

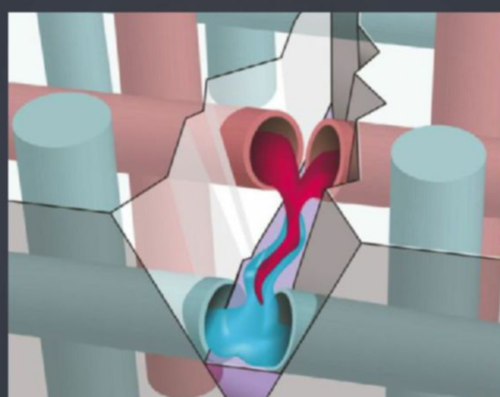
LOW COST OF OWNERSHIP

Self-healing approaches

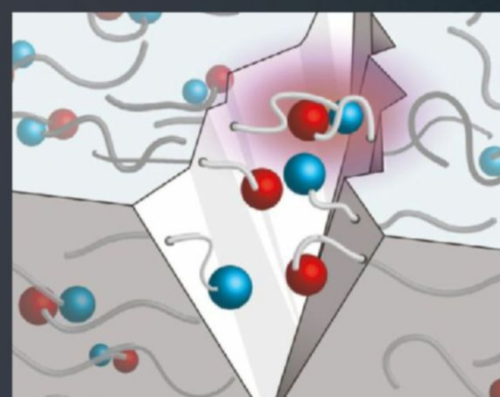
Understanding three methods by which plastics can be given self-healing properties



1 Embedded capsules
During manufacture, micro-capsules that contain a healing agent are embedded in the plastic. If micro-cracks form they breach the capsules, allowing the healing agent to mix with a catalyst in the plastic. The chemical reaction produces a plastic that fills the cracks.



2 Vascular approach
The snag with capsules is that, once the chemicals are used up, the same area can't be repaired again. The vascular method is similar, but the chemicals are supplied through tubes that are attached to pressurised reservoirs to repeatedly affect repairs.



3 Intrinsic self-healing
Intrinsic self-healing plastics don't respond to the development of micro-cracks but instead reverse the chemical reactions that cause those cracks. This reverse reaction has to be initiated manually – perhaps by heating – and causes broken chemical bonds to be repaired.

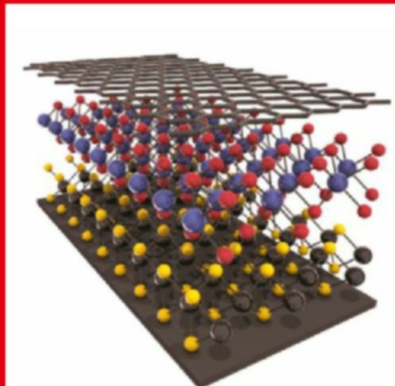
HETEROSTRUCTURES

Silicon electronic devices have, traditionally, been fabricated by etching and chemically modifying a silicon wafer. But researchers at Warwick University believe there's another way that not only offers an alternative, but will also allow strong and flexible electronic circuits to be created. In this new approach, two-dimensional materials are bonded together to form a three-dimensional stack with unique electronic properties.

Graphene is perhaps the best-known two-dimensional material, but in Warwick University's heterostructure, two different materials were used. By layering molybdenum diselenide ($MoSe_2$) and tungsten diselenide (WSe_2), a material with strongly enhanced photoluminescence was created with potential opto-electronic applications.

More generally, research into heterostructures of two-dimensional materials is employing a wide range of 2D substances. In addition to transition metal dichalcogenides, of which $MoSe_2$ and WSe_2 are just two, materials include boron nitride and, of course, graphene, with the aim of fine-tuning novel electronic properties. The up-and-coming field of quantum computing has been suggested as an application of bilayer heterostructures.

Heterosctructures of 2D materials could lead to stretchy electronic circuits, including flexible screens



Stacking 2D materials can result in very different properties from the constituent layers

VANTABLACK

Vantablack has been described as the closest thing to a black hole we'll ever see. Absorbing up to 99.965 per cent of light falling on it, Vantablack holds the record as the darkest substance ever made by humans. An interesting property is that any three-dimensional object coated with it is so black that it becomes extremely difficult to discern any surface features, so it appears to become two-dimensional. Vantablack coatings take the form of a forest-like structure of carbon nanotubes.

Developed as a coating, many of the proposed applications of Vantablack are technical, for example, in optical instruments carried onboard space probes. By reducing stray light in these sensors they are much more able to detect the dimmest and most distant astronomical objects. It has also been used in luxury, limited edition products. Its developers describe its aesthetic effect as adding depth and glamour and cite a limited edition watch, from Swiss watchmaker MCT, which costs £78,000 ($95,000).

BLACK HOLE
Absorbing 99.965 per cent of light, Vantablack is the darkest human-made substance ever created.

VANTA'S THE NEW BLACK

BLACKEST HUMAN-MADE MATERIAL

LONG-LASTING

WATER-REPELLENT

LIQUIGLIDE COATING

How to make materials that are permanently super-slippery

LiquiGlide is a coating designed at the Massachusetts Institute of Technology to be hyper-slippery and permanently wet. It is self-healing because the liquid coating will naturally flow to fill and cover any scratches that are made in the surface.

One of the key benefits is in product packaging. Imagine that the inside of a ketchup or mayonnaise jar is coated with LiquiGlide. Because the contents can't stick there will be no more waste and no more shaking to get it out. There are also medical benefits. Take a medical stent as an example. A small, self-expanding, metal mesh tube, stents are placed inside a coronary artery after narrowing to prevent the artery from re-closing. However, stents can clog due to the build-up of fatty solids. The slippery nature of a LiquiGlide coating could prevent this.

The oil industry also stands to benefit. By coating the inside of pipelines with LiquiGlide, friction can be reduced, thereby reducing the amount of energy needed to keep the oil moving. Alternatively, a whole range of things could be easier to clean and LiquiGlide could also offer the ultimate in waterproofing.

Super slippery surfaces aren't new. A lotus leaf has this property due to its highly textured surface, which creates an insulating cushion of air. Artificial super-hydrophobic surfaces have also been made previously, but have tended to wear out and were not safe for food applications. LiquiGlide could overcome these drawbacks.

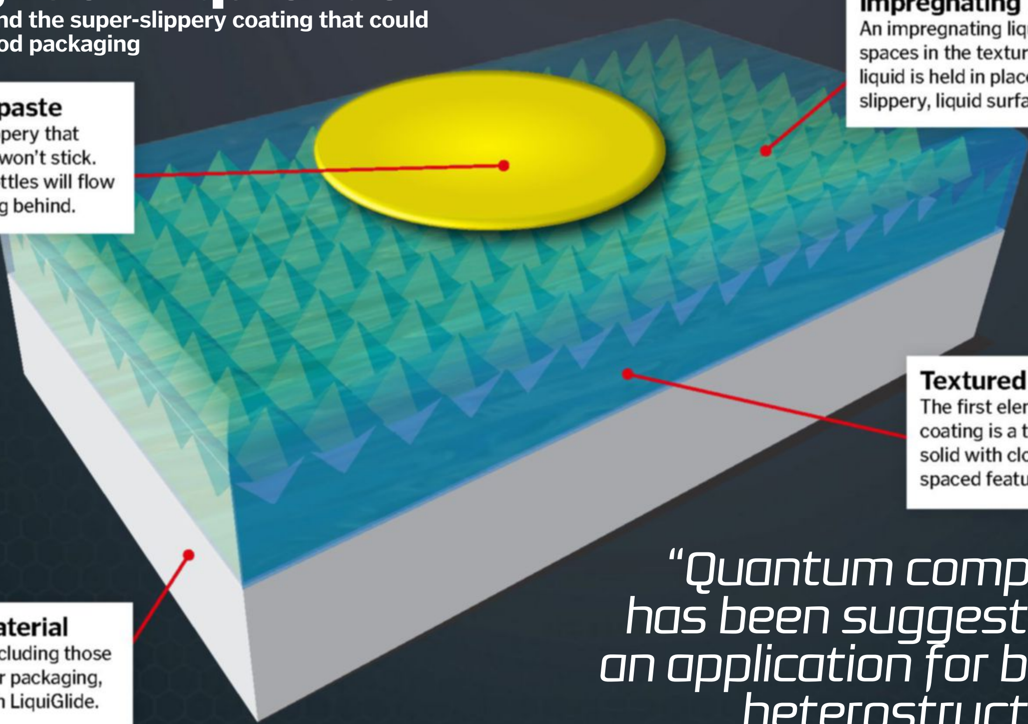
Every last drop

LiquiGlide coatings could prevent waste – how much residual product do we throw away in the average 'empty' container?

Lotion | Detergent | Condiments | Toothpaste

Spotlight on LiquiGlide

The secret behind the super-slippery coating that could revolutionise food packaging



Any liquid or paste
LiquiGlide is so slippery that liquids and pastes won't stick. The contents of bottles will flow out, leaving nothing behind.

Impregnating liquid
An impregnating liquid fills the spaces in the textured solid. The liquid is held in place, creating a slippery, liquid surface.

Textured solid
The first element of the coating is a textured solid with closely spaced features.

Packaging material
Many materials, including those commonly used for packaging, can be treated with LiquiGlide.

SLIPPING AND SLIDING

SUPER SLIPPERY

WATER-REPELLENT

LONG-LASTING

NONTOXIC

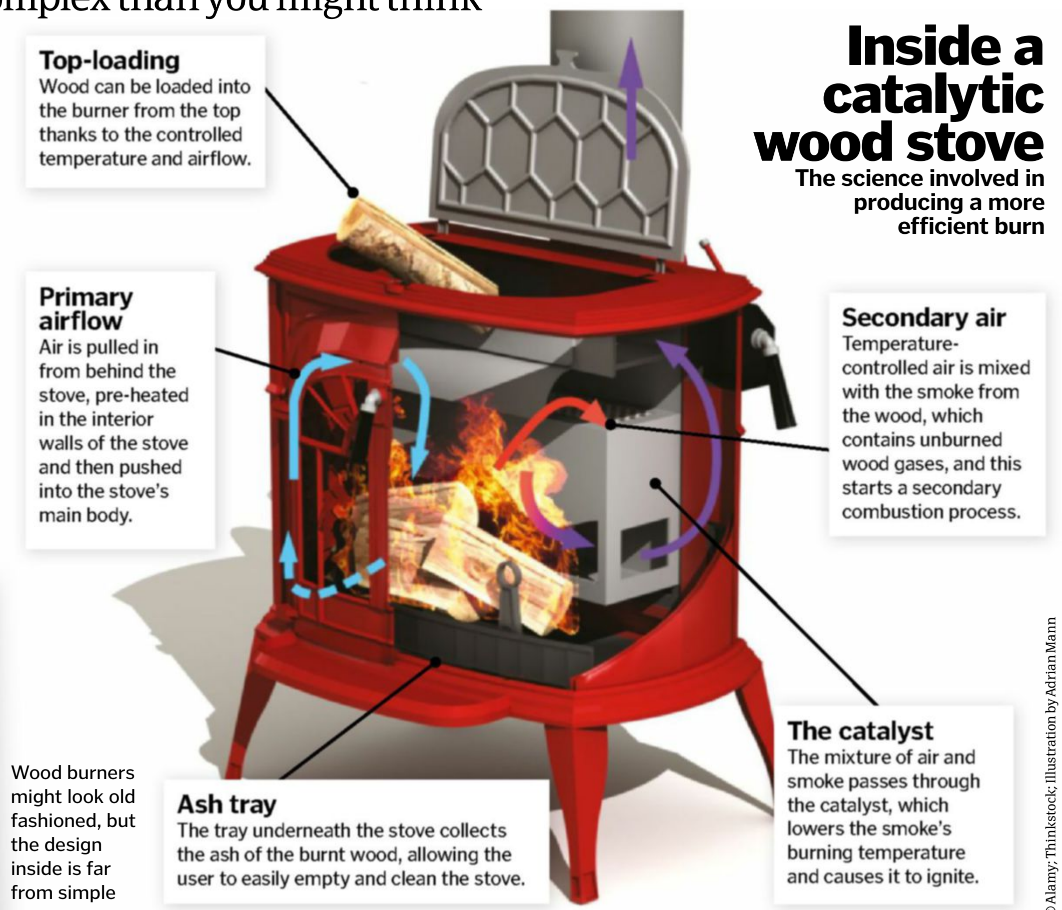
"Quantum computing has been suggested as an application for bilayer heterostructures"

How wood-burning stoves work

Burning wood is a lot more complex than you might think

You might think that a wood-burning stove is a simple device. Throw some wood into a metal box, set fire to it, and you're ready to go, right? In fact, the systems wood-burning stoves use are actually much more complex than that. Environmental rules mean that there are limits on what kind of emissions a stove can create, changing the way many are made.

There are two types of stove – catalytic and non-catalytic. Non-catalytic stoves are simpler, and require less maintenance, while catalytic stoves burn wood more slowly, have advanced features to make cleaning easier and are much more efficient. The downside is that they are more expensive and the catalyst inside needs to be replaced every five years on average.



Wood burners might look old fashioned, but the design inside is far from simple

Computer hacking

What methods can hackers use to access your data?

Logging keystrokes
Software installed unwittingly on a user's computer can be used to record every key a person hits, and the order they are pressed. This allows hackers to easily log usernames and also passwords.

Gaining backdoor access
One method of installing software like viruses is with what's called Trojan Horse. This finds weaknesses in an operating system or computer network and exploits this 'backdoor' to install the software.

Hacking passwords
There are several ways to do this, from using educated guesses at common passwords like 123456, to using software to try thousands of different passwords quickly to find a match, known as a brute force attack.

Creating zombie computers
A zombie computer is a device that has been taken over by a virus. It can be used along with other zombie computers to send spam or bombard a website with traffic, causing it to go down.

Installing a virus
Viruses are very clever programmes that piggyback off other software and run when you open the app in question. They can then trick users into buying software or secretly steal personal information.

Spying on email
Some software allows hackers to read the content of a user's emails. However, most modern email systems use complex encryption techniques to ensure messages are safe and cannot be intercepted.

Inside a recording studio

How do the professional musicians make their tracks sound so good?

A few decades ago, music studios were large, specialist locations filled with expensive equipment. High quality microphones, complicated mixing desks and soundproofing were all difficult to come by, which is why studios like Abbey Road and Sun Studios became the second homes of artists like The Beatles and Elvis Presley. Nowadays, equipment like this has become a lot more affordable, which has allowed many artists to create their own studios at home or simply record music in their bedrooms.

Traditional recording studios, however, are still very much around, and are often used by professional musicians to get the very best sounds for their albums. These studios usually have a main performance area, often itself called a studio, which is where the artist performs. This room usually has excellent acoustics to produce the best results when the artist plays.

The room will be wired up with a range of different microphones, some directly connected to the instruments being played, while others are placed around the room to pick up the audio as the sound waves reverberate. All of these sounds, as well as musical outputs from electric instruments like guitars, are fed into the editing area, where an engineer will use a mixing board to change the levels of each sound. Individual instrument sounds can be made louder or quieter, and the engineer can also control the bass, treble and other functions from the board.

Some musicians may also use effect boxes to change the way their instruments sound. These devices plug into the instruments themselves and alter the sound before the audio is fed into the mixing desk. There are all kinds of effects that can be added. For example, these boxes are what make a heavy metal guitar sound 'heavy'.

What's inside a recording studio?

What kind of equipment is used to make musical magic?

Artists can hear the studio engineer's instructions or feedback through their headphones

"Individual instrument sounds can be made louder or quieter in the mixing board"

Abbey Road's famous studios

One of the world's most famous music recording studios is Abbey Road, where The Beatles recorded almost all of their singles in the 1960s. The band named its 1969 album after the street that the studios are on, which made it world famous. Nowadays, the studio uses a mixture of digital equipment alongside custom-built vintage devices to create a really unique sound. The main stage inside the studio has remained mostly the same as it did back when the Beatles recorded their famous songs, but the building also contains several other studios. Abbey Road has an extensive collection of vintage microphones from the last 80 years, allowing artists to choose unique sounds, and a team of experienced sound engineers. The studio is still incredibly popular today, thanks to the mix of history and expertise on offer there.

DAY IN THE LIFE OF

An environment artist

How the lush and immersive environments in modern video games are created and tested

Naughty Dog is one of the best-known video game developers in the world. The creators of critically acclaimed titles including *Crash Bandicoot*, *Jak & Daxter*, *Uncharted* and *The Last Of Us*, the company's portfolio of games is renowned not just for its iconic characters and engaging storytelling, but for its aesthetic quality as well.

Martin Teichmann is an environment artist at Naughty Dog, and was part of the team that designed the levels in the best-selling and multi-award-winning *Uncharted 4: A Thief's End*. Martin modelled the buildings, vegetation and objects in many of the game's environments, helping transform them from concept artwork to captivating, interactive landscapes.

GETTING READY FOR THE TEST
9.30am

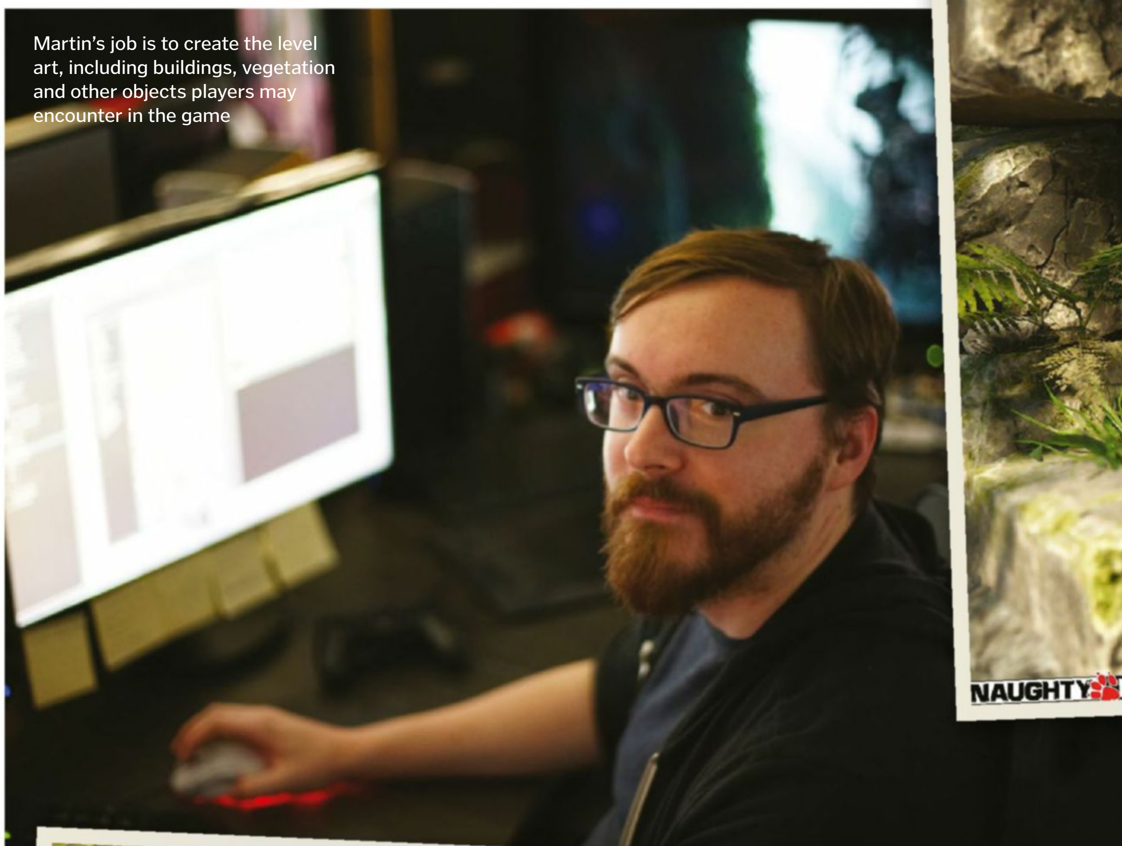
My role is to create the shapes of buildings, objects, vegetation and other details. We edit levels using Maya computer animation and modelling software. Today is the day of the play test, so I make some final tweaks to my level design to make sure it's playable. The last thing I want is the testers getting stuck within the level or the gameplay mechanics not working as they should.

SUBMITTING THE LEVEL
11am

When I'm finished with the changes, the level is given to the testers. I receive an email saying that it is now locked and from then on I'm unable to submit any more changes. If I tried to work on it while the testers were playing through, it could break the level. I'll then watch the play test as it's happening.

THE PLAY TEST BEGINS
12pm

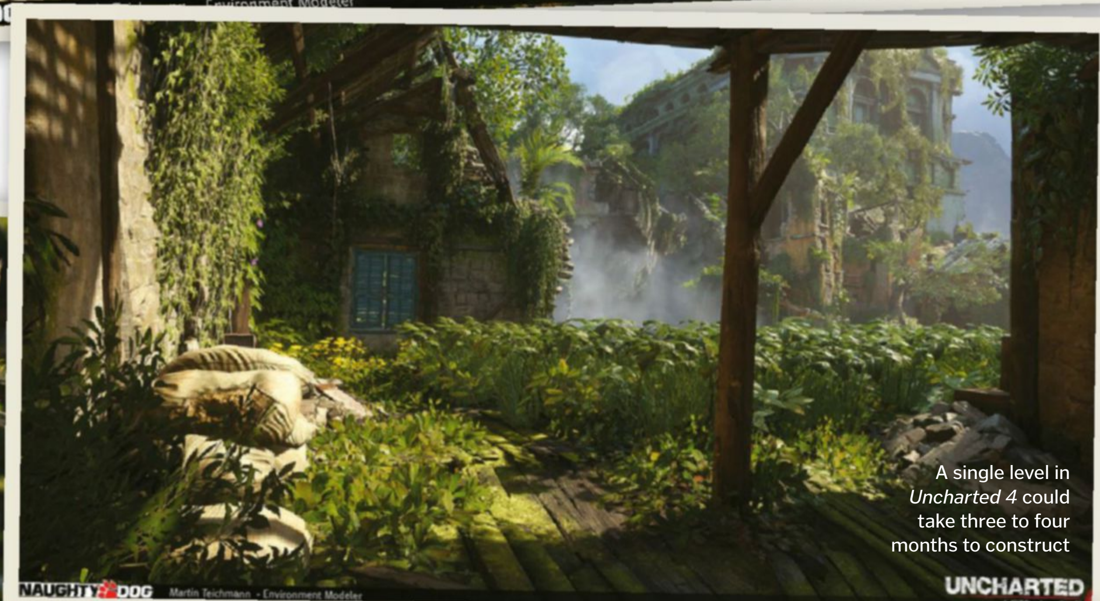
Play tests are really important, as you've been looking at this level for months so you know it so well, but you



Martin's job is to create the level art, including buildings, vegetation and other objects players may encounter in the game

Uncharted 4 sold over 2.7 million copies in its first week

Martin creates the objects for each level using concept artwork as a reference



A single level in *Uncharted 4* could take three to four months to construct

For Martin, one of the best parts of the job is when a level starts to come to life

can never tell how it really plays. We need to make sure everything works as it should. I'm always curious to hear their feedback. You learn a lot about your environment when it's played through by someone else. For example, if the testers get stuck a lot, I may need to consider making certain aspects of the level more obvious.

END OF THE TEST
2pm

When the play test is over, I'll be asked to make certain changes and adjustments to the level. They can be collision mechanics, more ledges to hang from, extra hand grips for climbing, additional cover objects the player can hide behind, that sort of stuff. The challenge is to keep the gameplay working how the testers and the designers want it, yet still making it as pretty as possible.

LITTLE TWEAKS
3pm

When changes are being made, I have to make sure they don't interfere with the gameplay mechanics or other aspects of design. For this level, I had a wardrobe I needed to put in and I had to look around for ages to find where I could place it, but later a designer mentioned that it was blocking another bit of the scenery that they had included. That is the most challenging part of the process, I feel.

FINISHING TOUCHES
6pm

Game tests are going on almost constantly until the very end of production. People play the level differently, so you get varied feedback and suggestions for changes. I can open up areas and make them accessible if they weren't before, add or remove vegetation and rubble, and if more objects are needed, I can outsource the creation of particular props to an external artist to work on.

END OF THE DAY
8pm

At the end of the day I submit my artwork onto the server. It is left unlocked so it can be accessed by a colleague if they need to work on something. The most rewarding part of my job is the moment where a level really starts to come together. There's a point when you can lean back and think "this is starting to look pretty cool!"

Bagged vacuum cleaners

Discover how these machines use scientific principles to keep our floors clean

When we see dust and hair being lifted from the floor by a traditional bagged vacuum cleaner, we tend to think that it is being sucked up. But that notion isn't strictly correct. Inside the vacuum cleaner casing is a motor that drives one or more fans. These fans spin rapidly and sweep along air particles in the process. As the air particles are pushed towards the vacuum cleaner's exhaust port (where the air escapes from the machine), the air density inside the casing becomes much lower than it is outside the air intake port.

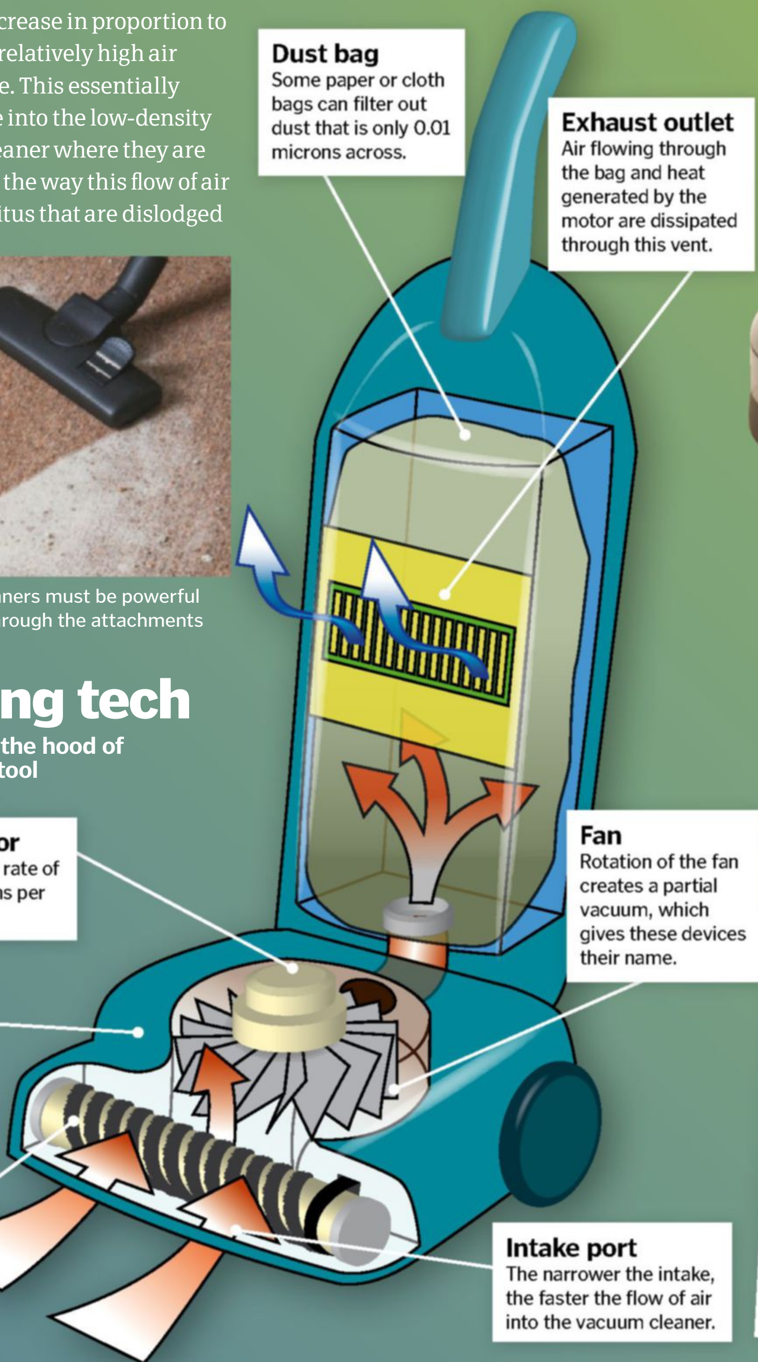
Density and pressure increase in proportion to each other so there is also relatively high air pressure outside the intake. This essentially forces air particles to move into the low-density area inside the vacuum cleaner where they are swept up by the fan. Along the way this flow of air picks up fragments of detritus that are dislodged by friction or a rotating brush near the intake. This continues as long as the fan is running.

After passing the fan, the flow of air moves through the vacuum cleaner and into the bag, which has minute gaps in its walls. These are too small to let dust particles through so the dust is deposited inside the bag as the air passes out. The principle is the same in vacuum cleaners with canisters instead of bags, except that the dust particles are captured by a filter before the air is ejected.

Motors in upright vacuum cleaners must be powerful enough to produce 'suction' through the attachments

Dust-busting tech

See what goes on under the hood of this household cleaning tool



Robotic vacuums

The Roomba 980 is an autonomous vacuum cleaner. It uses similar principles to a standard model, only its dust collects in a bin rather than a bag and its intake port has rubber rollers instead of brushes. To navigate it uses an algorithm called vSLAM (Visual Simultaneous Localization and Mapping) that can map out obstacles based on visual data captured by an on-board camera.

The Roomba 980 will clean along parallel lines but adjusts its route when necessary using on-board sensors. For different floors, the power output of the lithium ion battery-driven motor will modify the strength of the vacuum. iRobot claim the Roomba 980 can detect dirt and clean more thoroughly where there is lots of it. Wireless connectivity lets users adjust settings through a mobile app, and the Roomba 980 automatically returns to its charging station when its battery runs low.

Robot vacuum cleaners are designed to access hard-to-reach places more effectively

Accumulated dust, particularly large particles, will hinder airflow inside a vacuum cleaner, reducing its effectiveness

Massage chairs

Sit down and get comfy. It's time to learn about massage chairs

Relaxing after a long day of school or work can be tough. But with some smart tech, massage chairs help to alleviate the stresses of each day by relaxing your body, without a human massage therapist in sight. The tech inside these chairs is actually simpler than you think, and while different manufacturers use different designs and mechanisms, there are some that are the standard across most chairs.

The simplest massage chairs work using vibration motors, similar to those found in smartphones and video game controllers. These motors have a weighted wheel or gear and when it spins it creates a vibration, which helps to provide a massage to your muscles.

However, this isn't the only way to give a massage. Other chairs use rollers that move in defined patterns within the chair's frame. These rollers are designed to simulate the movement of human hands on different muscles. In some more advanced chairs, these rollers can move in multiple directions or even in circles. These rollers are usually applied only to the person's back, as they are designed to run along predefined paths.

Other techniques include airbags stored in the arms and other motors that tap or press into specific parts of the body. The airbags inflate and deflate to squeeze the arms and legs gently, while the motors can create a tapping sensation similar to the 'karate chop' massage technique. Bring all of these technologies together, and allow them to be controlled with a handset, and you have your very own robotic masseur.

Get massaged… by water?!

Have you ever sat in a hot tub or jacuzzi and enjoyed the massage provided by the jets of water? It can be very relaxing, but getting wet often isn't practical when you just have a few painful muscles. Instead, some massage chair designs use jets of water that flow through pipes built into the chair itself. These water jets create a similar sensation to that of a jacuzzi without the user having to get wet or climb into a large jacuzzi that would require a lot of space to accommodate.

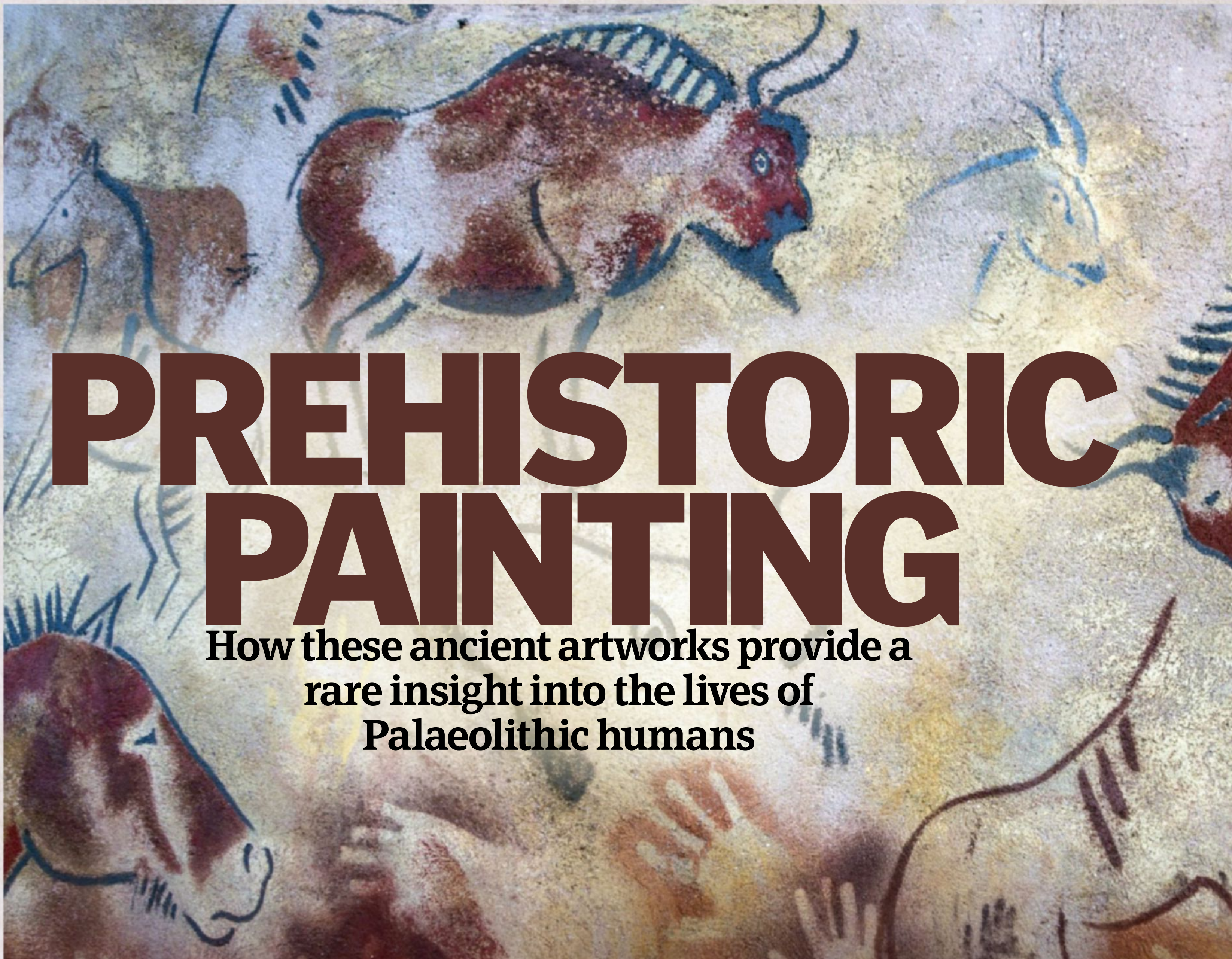
Heating and cooling systems inside the chair itself can also change the temperature of the water to the user's specification. In the original design, the power of the water caused bulging in the front of the chair, so bars were added to strengthen the membrane between the water and the user and keep everything in place.

Water-based massage chairs are still rare, but water beds and tables are becoming more common

Inside a robotic massage chair

See how motors and gears can replicate a spa experience in the comfort of your own home

"The simplest chairs use vibration motors, similar to those in smartphones"



PREHISTORIC PAINTING

How these ancient artworks provide a rare insight into the lives of Palaeolithic humans

Prehistoric cave paintings are believed to be among the first examples of human art. The remnants of images found in caves today provide archaeologists with a fascinating insight into the world of our Stone Age ancestors.

So how did they make the paint? Black paints could be made from a simple mixture of charcoal and a binder, such as saliva or animal fat. The earliest coloured paints were made from naturally occurring minerals (known as pigments) such as iron oxides, which were ground into a powder before being mixed with a binder. These pigments were in high demand, and some prehistoric artists may have travelled 40 kilometres or more to gather them.

To make a typical cave painting, an outline was scored on the wall with a sharp stone, then marked out with charcoal. The image could then be filled in with a coloured pigment paint, and shaded to make it three-dimensional.

The majority of cave paintings are illustrations of animals that roamed the land nearby, including lions, rhinos, bears and even sabre-toothed cats. Images of the humans themselves are much less common. One theory for this is that it was believed that the artwork was a link to a spirit world, and the depictions would increase luck when hunting. Campfires in the caves helped to give the impression that the painted creatures were alive, with the illustrations dancing on the walls. Outlines of human hands, also known as hand stencils, are a common sight among cave paintings, thought to be a sort of artist's signature.

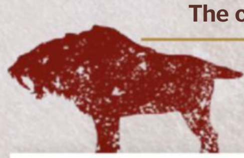
Scientists can estimate when a cave painting was made using radiometric dating, either using the rate of decay of the isotope carbon-14 in the pigments, or the rate of uranium decay in the surrounding rocks. Some paintings in Europe are thought to date back as far back as the Upper Paleolithic period, making them up to 40,000 years old. The European examples are perhaps the most well-known, but prehistoric cave art have been also been found in Africa, Asia and Australia, with (relatively) more recent examples in the Americas dating back nearly 10,000 years. Based on the discoveries so far, cave art seems to have become less popular as warmer climates allowed humans to begin settling outside of caves.

Discoveries of prehistoric art continue to fascinate us today and provide a unique insight into the culture of our distant ancestors.

In archeological terms, cave art is also known as 'parietal art'

The prehistoric palette

The colours and shades used to illustrate the Stone Age world



Ochre

Ochre pigments can come in shades ranging from red to yellow to brown depending on its mineral blend, but they all contain iron oxide. Its texture allows it to be easily mixed with other pigments.

Carbon black

Monochrome paintings were a simple mix of carbon black and a binder. The colour was made from burning wood or plants, which created charcoal. It was often used as a ground layer for a polychrome image.

Kaolin

Kaolin is a white-coloured clay and one of the Earth's most abundant minerals. Its name originates from the town of Gaoling in China, which is renowned for having rich kaolin deposits.

Umber

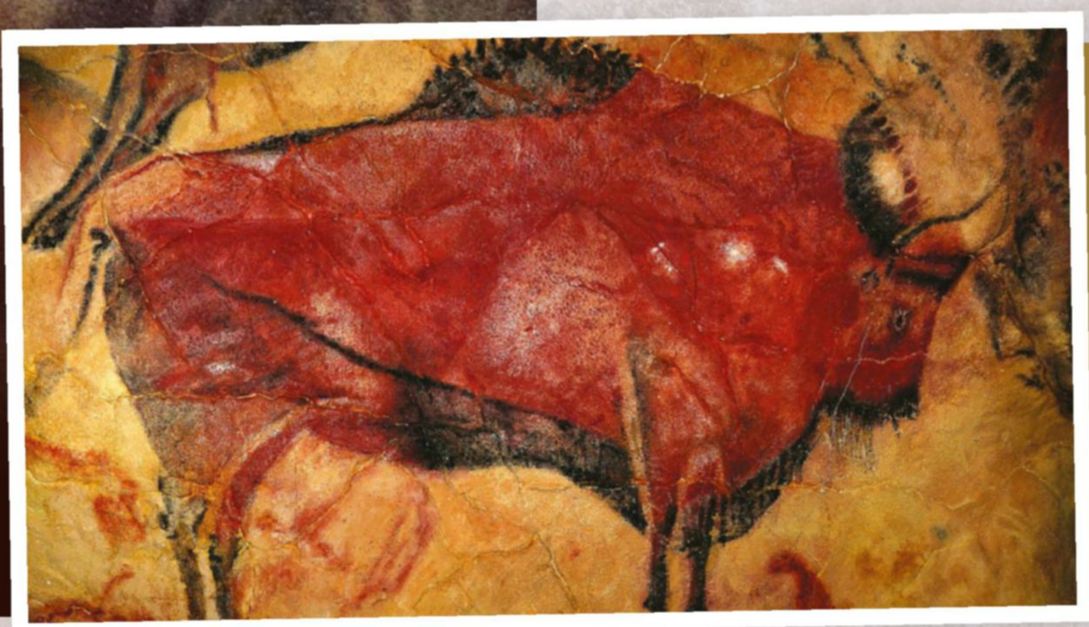
Umber is another combination of iron and manganese that is darker than both sienna and ochre. The shade of its reddish-brown colour is dependent on which mineral was dominant in the mix. It could be heated to the even darker colour of burnt umber.

Manganese oxides

One of the darkest colours used, manganese oxide could create shades that were brown, grey or black. Manganese deposits weren't common in caves adorned with artwork, so it's assumed painters would trek long distances to find a source.

Sienna

A mixture of iron oxide and manganese oxide, raw sienna is a pigment with a yellow-brown colour. When heated, it turned into burnt sienna, which is darker in tone and redder in colour.



Green and blue

Cave art typically features red, brown, yellow and black, but none of the paintings, it seems, included blue or green. This can be explained in part by the lack of natural pigment sources for these shades. In the Palaeolithic period, obtainable blue-coloured minerals were rare, especially in Europe. Blue was used in later eras by the ancient Egyptians, who used powdered azurite to make blue-coloured jewellery. The omission of green shades is more difficult to comprehend, as green coloured minerals like malachite and terre-verte were abundant. One of the reasons given for the lack of green colour is that it may have simply not shown up as well as red or brown does under fire or torchlight.

Clay ochre could be red, yellow or brown, but not blue or green

Hand stencils

The techniques used to create the perfect prehistoric hand silhouette

1 Tools for the job

To create a hand stencil, researchers think that prehistoric humans used hollow bones or reeds to blow paint through, and a shell to hold the paint in. The pigment used to make the paint was ground into powder and could be sourced from various minerals.

2 Making the paint

The powdered pigment was mixed with a binder in the shell using the reed or bone. Researchers trying to recreate prehistoric hand prints found that to make a paint thin enough to spray, the Palaeolithic painters likely used water as a binder.

3 Creating the stencil

The artist placed one hand on the wall, held one of the reeds/bones in their mouth, and held the shell and second tube (dipped in the paint) in their other hand. Blowing through one tube across the top of the other created a cloud of colour spray on the wall.

4 Finishing touches

When the artist removed their hand from the wall, they left a silhouette with colour all around it. More colours could be added with brushes, or a charcoal outline could be drawn around the hand. Bumpy walls could also help create a 3D effect.

Whose hands were they?

Experts can determine the gender of the person who made a stencil with over 90 per cent accuracy. The technique that is used is part of a study called geometric morphometrics. Digital versions of modern male and female hand stencils were made and used as a template when measuring those of prehistoric hands. The hands were then compared based on palm shape, which has been found to be a more useful indicator of gender than just measuring finger length and hand size. The study reinforced that both genders would often produce stencils. Researchers can also make an educated guess regarding the handedness of the artists, as the hand that is on the wall would most likely be their weaker side, and the dominant hand would be the one used to hold the pigment.

Hand stencils in Cueva de las Manos (Cave of Hands) in Argentina, created between 13,000 and 9,000 years ago

The world's weirdest pigments

Our artistic ancestors were quite resourceful

Mummy brown

A hugely popular pigment during the 16th century, this was made from the remains of ancient Egyptian mummies. Mixed with myrrh and white pitch, it made a reddish-brown colour.

Tyrian purple

This pigment was made from a dye extracted from murex shellfish. A symbol of imperial authority in the Roman Empire, it was used to colour the emperor's toga.

Lead white

Long before it was known to be poisonous, lead white was used as a paint pigment and also in makeup. One theory is that it contributed to Van Gogh's deteriorating mental health.

Uranium yellow

This yellow-orange pigment was used to create coloured glass and glazes for ceramics. However, this stopped when it was found to be a radioactive and highly toxic substance.

Carmine

Carmine is a deep red colour that has long been associated with royalty and nobility. It is made from the carminic acid that oozes out of some species of crushed beetles.

Cave art across the world

The best examples of parietal paintings across the globe, from France to Australia

LASCAUX

France / 18,000 - 13,000 BCE

With hundreds of paintings and drawings and over 1,500 engravings, Lascaux is one of the best sites for prehistoric art on Earth. The caves include depictions of bison, mammoths, aurochs, lions and wolves among others.

PETTAKERE CAVE

Indonesia / 38,000 BCE

These Indonesian paintings are believed to be proof of prehistoric island-hopping in southeast Asia. The cave includes what are believed to be the oldest hand stencils on Earth.

CUEVA DE LAS MANOS

Argentina / 13,000 - 9,000 BCE

The Cave of Hands plays host to some of the oldest known cave paintings in the Americas. The artwork varies from hunting scenes to hand stencils and is red or black in colour.

KIMBERLEY

Australia / 50,000 - 5,000 BCE

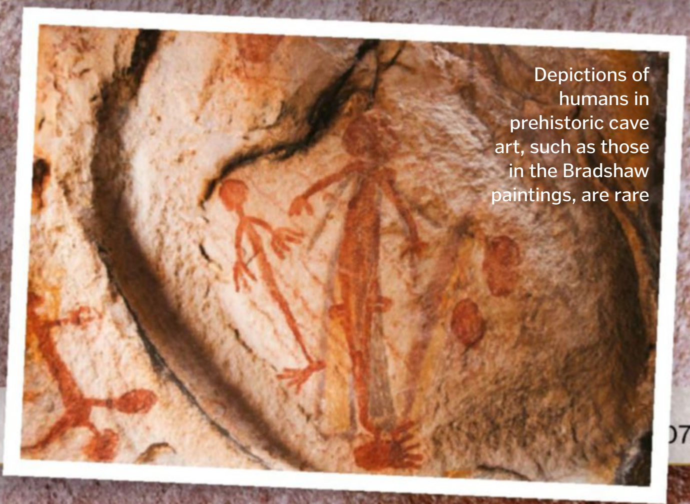
Known as the Bradshaw or Gwion Gwion paintings, the age of the art itself is difficult to determine, but it's possible that this cave is home to some of the oldest artwork of human figures in the world.

"Some paintings in Europe are thought to be up to 40,000 years old"

BLOMBOS CAVES

South Africa / 100,000 - 70,000 BCE

Archaeologists have unearthed the remains of what appears to be a rudimentary paint workshop in these caves. They found engraved blocks of ochre (shown on the right), shell 'palettes', bone 'spatulas' and grinding equipment.



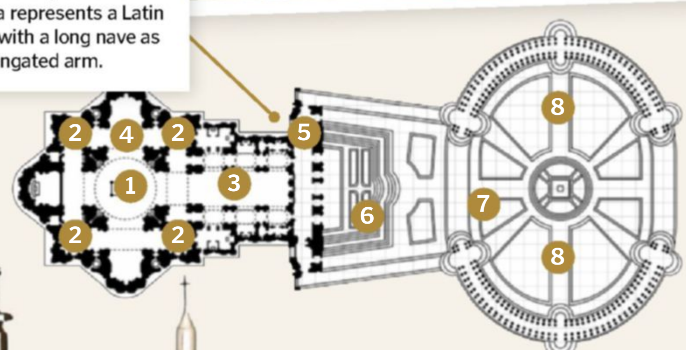
Depictions of humans in prehistoric cave art, such as those in the Bradshaw paintings, are rare

Visitors can climb 551 steps to the top of Michelangelo's dome

Dome
Designed by Michelangelo, the dome measures 43m in diameter and is 137m high.

The view of St Peter's Square from the top of the basilica's dome

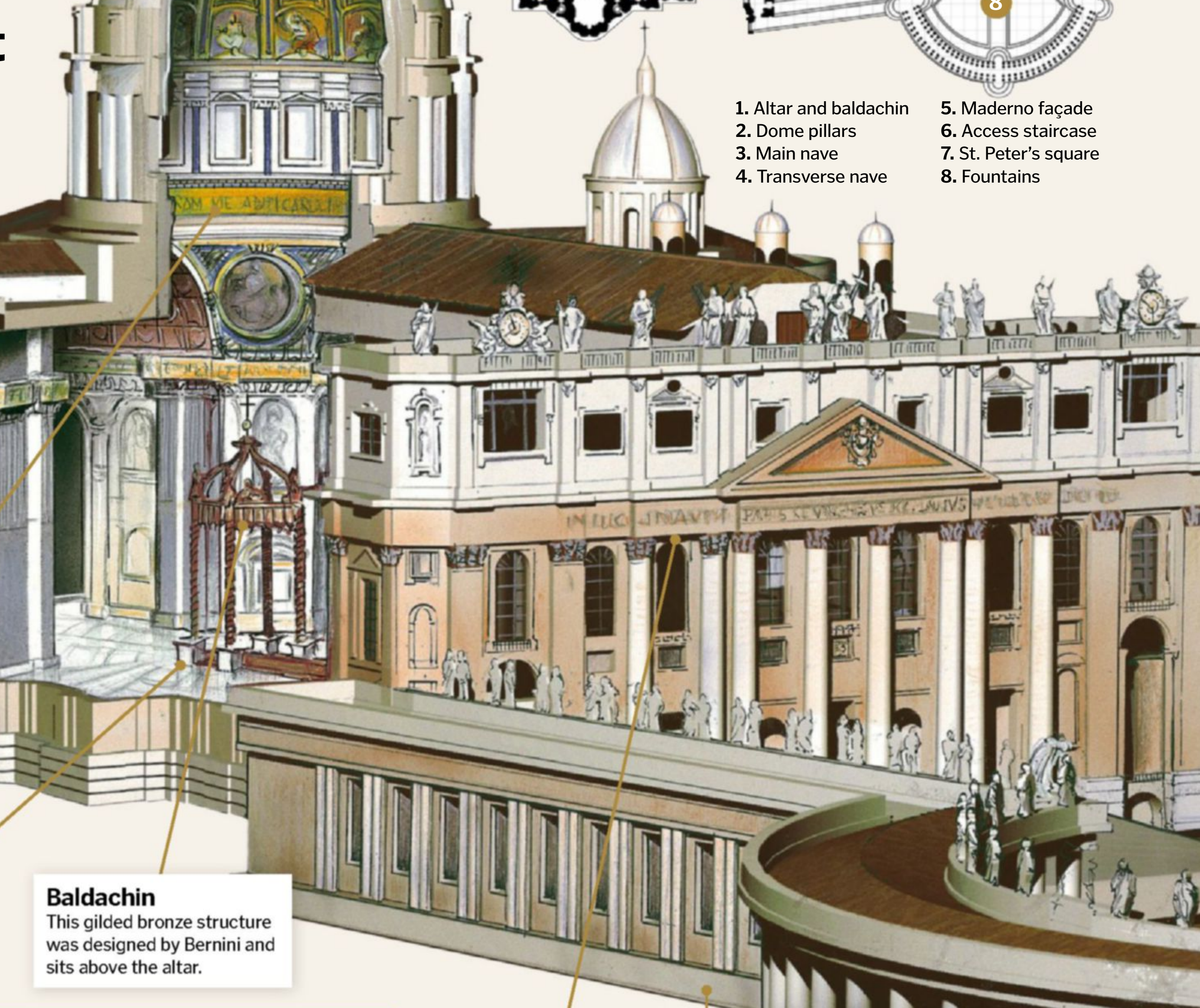
Floor plan
The final shape of the basilica represents a Latin cross, with a long nave as the elongated arm.



1. Altar and baldachin
2. Dome pillars
3. Main nave
4. Transverse nave
5. Maderno façade
6. Access staircase
7. St. Peter's square
8. Fountains

A group effort

Explore the different features added by each of the basilica's leading architects



Inscription
The Bible quote "You are Peter and on this rock I will build my church, and I will give you the keys to heaven" is written in Latin around the dome.

St Peter's tomb
St Peter is thought to have died around 64 CE and his tomb is believed to be located directly beneath the basilica's altar.

Baldachin
This gilded bronze structure was designed by Bernini and sits above the altar.

Façade
Designed by Maderno, this Baroque façade features 13 statues and three balconies.

Diverging walls
By moving away from each other, these two walls create an optical illusion that amplifies the façade and dome.

Vatican grottoes

Beneath the basilica lie chapels dedicated to various saints and tombs of kings, queens and popes dating back as far as the 10th century. The holiest of them all is the tomb of St Peter, who was martyred and crucified during Emperor Nero's great Christian persecution. The tomb, which was discovered during excavations in the 1940s, contained the bones of a man in his 60s and was inscribed with the words 'Peter is here' in Greek, but there is still some debate between archaeologists and the Church about whether the remains are his.

It's thought St Peter's tomb is beneath Bernini's baldachin

St Peter's Basilica

The Vatican City's spectacular church took 120 years and several redesigns to complete

As one of the world's largest churches and most renowned examples of Renaissance architecture, St Peter's Basilica is a breathtaking sight. But this stunning building has a complicated history.

Its construction began in 1506 under the orders of Pope Julius II after the Old St Peter's Basilica had fallen into disrepair. The original church was commissioned by Emperor Constantine of the Holy Roman Empire and constructed around 329 CE, and marked the site where it was believed St Peter, considered by Roman Catholics to be the first Pope, had been buried. Christian pilgrims travelled to the site from all over Europe, so when it was time to replace the structure, something much bigger was needed.

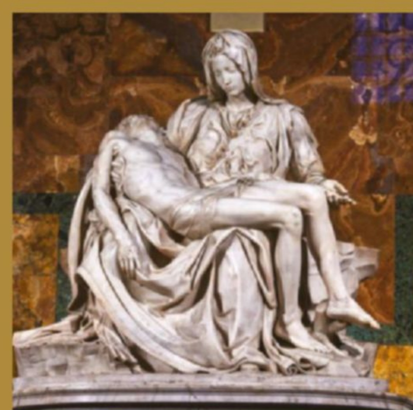
The task of designing it was given to Donato Bramante, one of the greatest architects of his time, who opted for a Greek cross floor plan with four equal arms and a large central dome. However, upon Bramante's death in 1514, several other architects proposed modified plans featuring an elongated Latin cross floor plan. For over 30 years construction was halted, until Michelangelo stepped in with a simplified version of the original design. When he died in 1564, the church was almost finished, and so his pupil, Giacomo della Porta, was left to complete the dome. However, even though the main structure was in place, debate still raged about the design, and when Carlo Maderno took over the project in 1605 he decided to turn it into a Latin cross. He also added the façade, which slightly obscured the dome, and so Bernini later constructed the colonnade in St Peter's Square to amplify its view.

Today, the basilica is still a place of pilgrimage and is considered one of the holiest Catholic shrines. While not the Pope's official seat, it's where he gives his first blessing upon election and addresses crowds at Christmas and Easter.

"Even though the main structure was in place, debate still raged about the design"

Basilica's treasures

The lavish interior of the basilica is home to many famous works of art, including Bernini's bronze baldachin and Arnolfo di Cambio's statue of St Peter, whose right foot has been significantly worn away by those who caress it to show their devotion to the saint. However, the most famous work is perhaps Michelangelo's *Pietà*, a sculpture depicting the body of Jesus after his crucifixion, lying across the lap of his mother Mary. It was created in 1499, when Michelangelo was just 24 years old, and is the only piece he ever signed as his name can be seen on Mary's sash.



Michelangelo's *Pietà* sits behind thick glass in the basilica's first chapel

Egyptian obelisk
This ancient structure was brought to Rome in 37 CE and transferred here in 1586.

Holy sculptures
Above the columns sit 140 statues of Christian saints, each 3.2m high and built by Bernini's pupils.

Colonnade
Bernini set out 296 columns in rows of four, arranging them in semi-circles to provide an open-armed welcome to visitors.

The history of Central Park

How did such a huge area of New York City become a green space?

If you look at the huge, sprawling space in New York that is occupied by Central Park, you probably won't realise quite how much it has changed since it was first created. The land, acquired by the City of New York in 1853, was over 700 acres of mostly barren swampland.

The story of Central Park began in the 1840s, when wealthy merchants and landowners urged the state to consider a public ground that would compare to parks in London and Paris. After many debates over the size and location of the park, a huge area in central Manhattan was chosen. In all, 9,792 standard 25 x 100-foot (7.6 x 30.5-metre) building plots were acquired for a grand total of over $5 million. At the time, this area was distant from the built-up area of the city, which was mainly in south Manhattan. The land chosen was uneven terrain, with rocky outcrops and swamps dotted around, making it undesirable for building. However, that didn't mean that there was nobody living there; in fact, around 1,600 poor residents were displaced by the project, including a stable African-American settlement in Seneca Village.

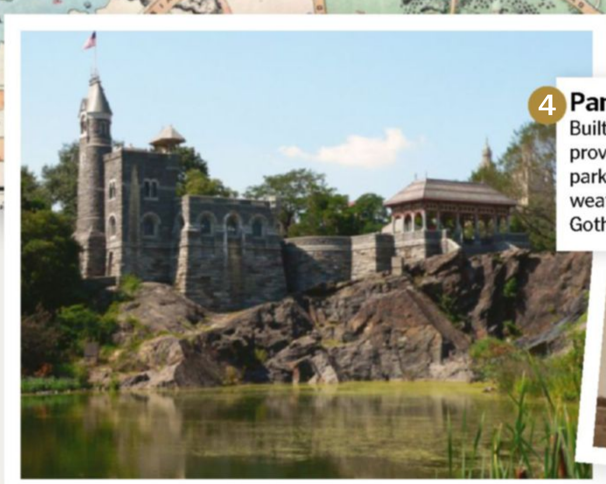
Converting this space into the beautiful park you see today was an enormous task. In 1858, a landscape design competition was held to choose the style and layout of the park, and work began soon after. It's estimated that 20,000 workers were involved in reshaping the land, and 260 tons of gunpowder was used to blast through the rock on site. Over 270,000 trees and shrubs were planted in the park, and a new reservoir was constructed. In the winter of 1859 the first part of the park opened to the public.

Construction continued for many years, and the cost of building the park rose to almost $4 million. In 1871, the now famous Zoo was given permanent quarters, and quickly became the park's most popular feature.

Planning Central Park

Building this vast public space was a huge job

1 Walk past an Egyptian
This genuine ancient Egyptian obelisk is one of a pair (the other is in London) and is the oldest outdoor monument in New York City.



4 Panoramic view
Built in 1869, Belvedere Castle provides excellent views of the park, and also houses a weather station. It is a mix of Gothic and Romanesque style.

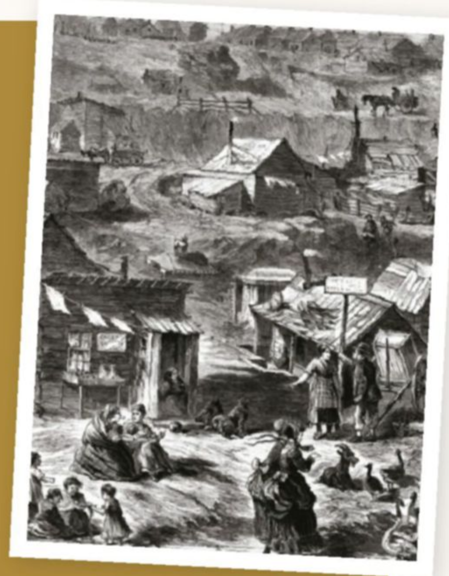
3 Bethesda Terrace
This terrace was one of the first structures built in Central Park. The lower terrace features the beautiful Bethesda Fountain.

The park stretches from 59th Street all the way to 110th Street

The history of Seneca Village

Seneca Village is an area within Central Park that looks like any other, but there is a lot of history hidden in the land. Nearly 200 years ago, in 1825, Andrew Williams and Epiphany Davis became the first African-Americans to purchase land in Seneca Village. Within four years, nine substantial houses had been built in the area, which was near the Hudson River (for fishing) and a natural spring.

By 1855 a census indicated that Seneca Village was home to around 250 people in 70 houses. However, when the plans for Central Park were made, the New York State legislature used a rule called 'eminent domain' to take this private land for public use, and compensate the owners in return. The community was forced to leave and the houses were demolished to build the park. Modern excavations in the area are now uncovering artefacts and stone foundations that tell us more about how the community lived.

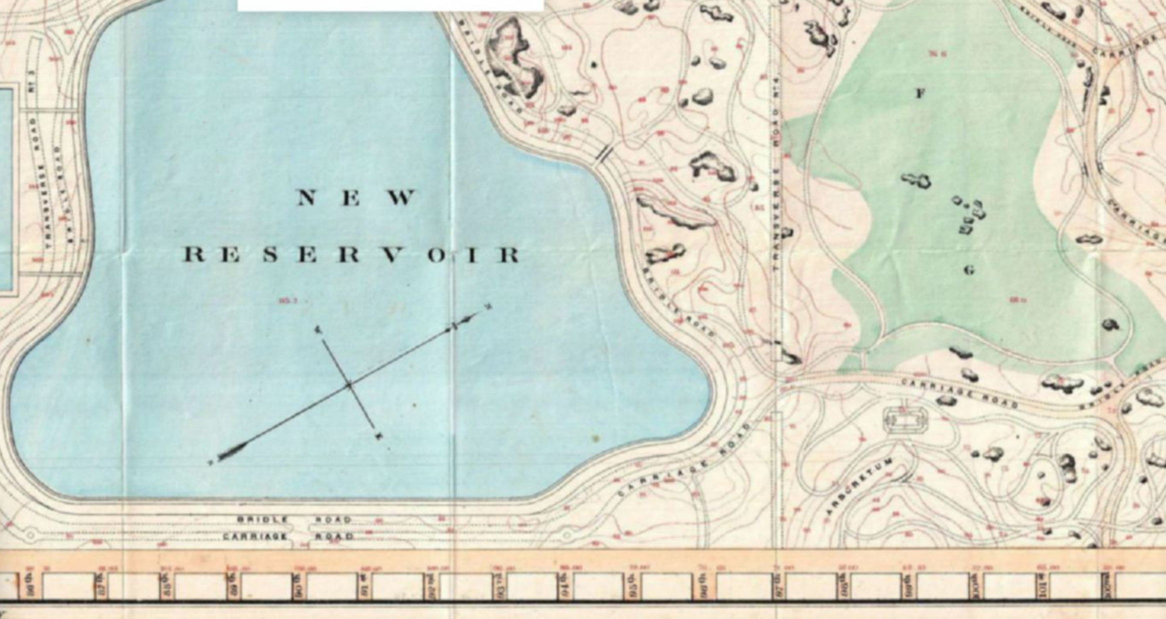


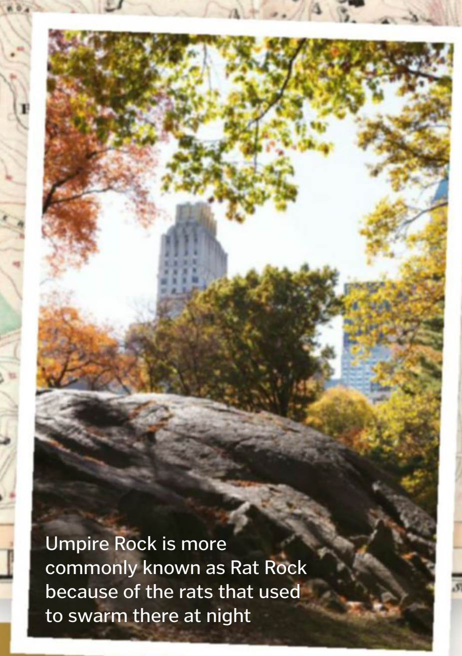
Seneca Village was home to African-Americans and European immigrants

"Creating the beautiful park you see today was an enormous task"

2 Over the water

Bow Bridge was the first cast-iron bridge in the park, and is the second-oldest in America.





Umpire Rock is more commonly known as Rat Rock because of the rats that used to swarm there at night

Five Central Park facts

Real history
Umpire Rock is one of several points where the bedrock of New York City is exposed. The rock was formed hundreds of millions of years ago during the Paleozoic era.

Sheep Meadow
The iconic Sheep Meadow really did use to be home to sheep. They were kept at the Tavern on the Green, and were let out to graze twice daily.

No racing!
The curved roads within the park were designed to stop people racing their carts and injuring people. Now people race their bikes along the paths instead!

No picnics!
Strict rules in the first decade of the park's existence meant that group picnics were prohibited within the park, which discouraged a number of less wealthy families from visiting.

No ball games!
When the park was first completed, schoolboys were only allowed to play ball games on the lawns if they had a note signed by their principal.

Typewriters

The origins of the mechanical writing machines that influenced modern keyboard designs

For most of the 20th century, almost every house, office and school had a typewriter. This mechanical device allowed people to write rapidly with neat, uniform text .

Each key on a typewriter is connected via a lever to a type hammer, which is a metal bar with the key's corresponding letter or number embossed on the end of it. When a key is pressed, the lever swings the hammer towards the paper. A thin ribbon coated in ink is raised in front of the page, so that as the hammer strikes, it presses the ribbon on to the paper behind it, leaving an ink impression of the symbol.

The keyboard mechanism works in tandem with the carriage that holds the paper, moving along by the length of a key each time you type so the letters don't overlap. In some models, nearing the edge of the page would trigger a bell to alert the typist. They would have to reset the carriage to start the next line of text by operating a lever on the side of the machine.

The first typewriters were powered purely by a typist's fingers, but some later models incorporated electronic motors, so keys only required a light touch. Some writers today still prefer the use of typewriters over computers, as their simplicity minimises distractions.

British engineer Henry Mill was granted the first recorded patent for a typewriter in 1714

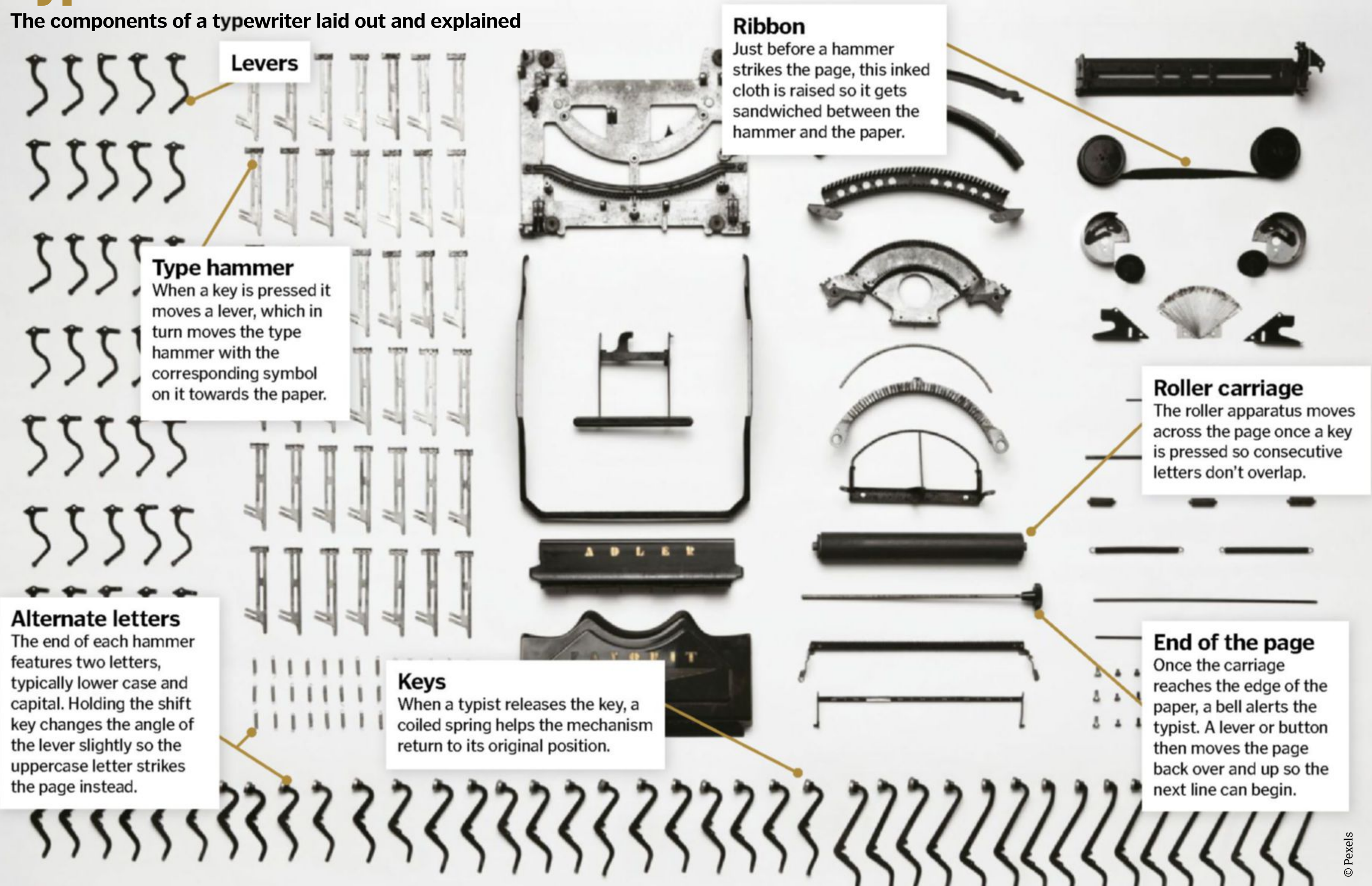
QWERTY keyboard layout

Why are the keyboards on typewriters, smartphones and computers laid out the way they are? The reason dates back to the 19th century. Christopher Latham Sholes, one of several men credited with the invention of the first typewriter in the US, noticed that if you typed too quickly, keys positioned close together could jam. To try and reduce this irritating feature, Sholes purposely spaced the most widely used keys apart. The QWERTY system was born. Today, these hammers are no longer used, but the QWERTY keyboard remains as it's what everyone knows. Another layout is the Dvorak keyboard, which places the most used keys on one row to make the typist use both hands as much as possible.

The QWERTY keyboard gets it name from the layout of the letters on the top left side

Typewriter teardown

The components of a typewriter laid out and explained



Cassette tapes and players

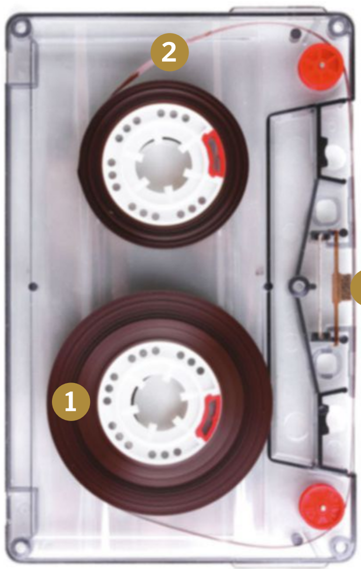
The retro device that made music portable before the introduction of CD and MP3 players

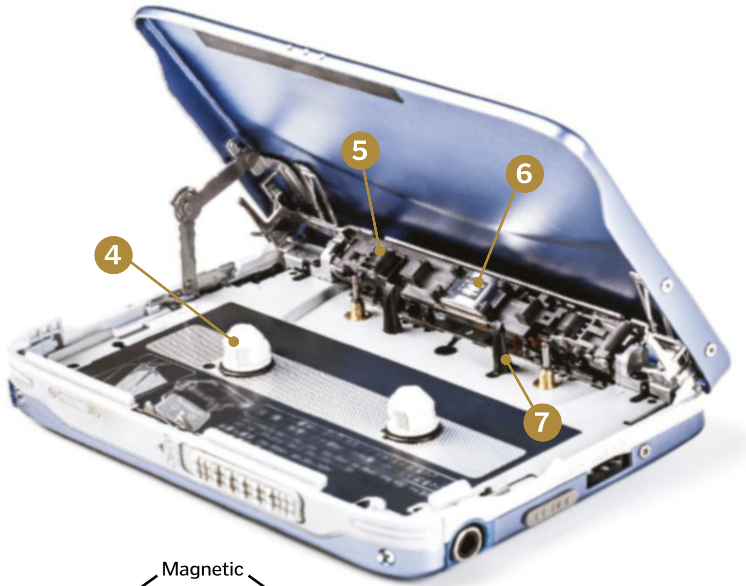
Cassette players were initially designed for use as dictation machines, but were soon adopted as music players. These devices contained sprockets (to wind the cassette tape), a capstan (to control the speed of the tape) and, most importantly, the record and playback heads; tiny electromagnets that turned sound into magnetic patterns and vice versa.

The tape inside audio cassettes contains iron oxide, a ferromagnetic material, meaning it can be permanently magnetised. When recording audio, a microphone converts sound waves into a changing voltage, which is then boosted by an amplifier. The electrical output from the amplifier is sent to the recording head. The varying voltage causes the recording head to generate a changing magnetic field, which the tape passes through as it moves from one reel to the other. As the tape moves by the recording head, the iron oxide grains in it align in the direction of the magnetic field, producing a pattern that represents the changing sounds detected by the microphone.

Playback essentially involves the reverse of this process. As a magnetised tape passes by the playback head, its recorded pattern induces a voltage in the electromagnet, so the magnetically-aligned pattern on the tape can be 'read' and converted into a voltage. This signal is then amplified and sent to a speaker to reproduce the audio that was initially recorded.

Tape recorders also contain an erase function, which feeds an ultrasonic signal to the tape to remove any alignment patterns from past recordings. The flexibility of being able to tape over old recordings, combined with their compact size, are among the reasons why cassettes players became such popular gadgets among music lovers on the move .





1. Supply reel
The tape is fed from the supply wheel and into the take-up reel as the sound recording plays.

2. Tape
The tape is coated in a lubricant to prevent it wearing out the other parts.

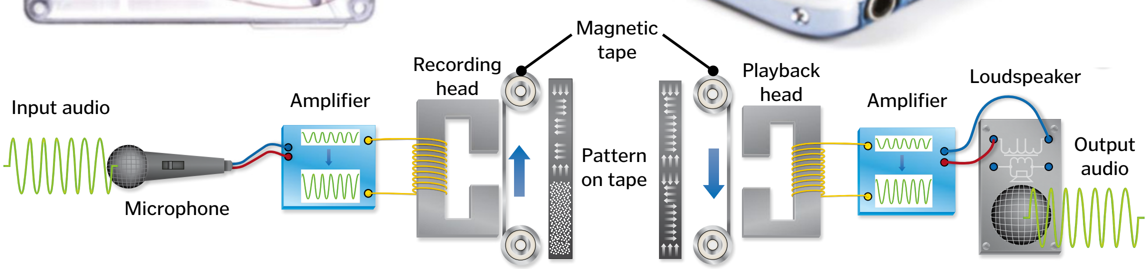
3. Pressure pad
This small, spongy pad makes sure the magnetic tape maintains good contact with the record or playback head.

4. Sprockets
These connect to the spools and spin to move the tape during playback, recording, fast-forward or rewind.

5. Erase head
This electromagnet is powered by a high-frequency source to remove any recordings already on the tape so the cassette can be re-used.

6. Electromagnet
The record and playback heads are two small electromagnets that can write on or read the magnetic tape respectively.

7. Capstan
This spins at a precise rate to control the tape speed, ensuring the music is recorded or played at the intended speed.



The recording head transforms the audio into a specific pattern on the magnetic tape…

…The playback head reads the pattern and translates this back into the original audio signal

The evolution of portable music

1954
The Regency TR-1 was the first transistor radio available on the consumer market and the first truly portable mass-market radio.

1979
The audio cassette tape went portable in 1979 with the release of the Sony Walkman, which became a global success.

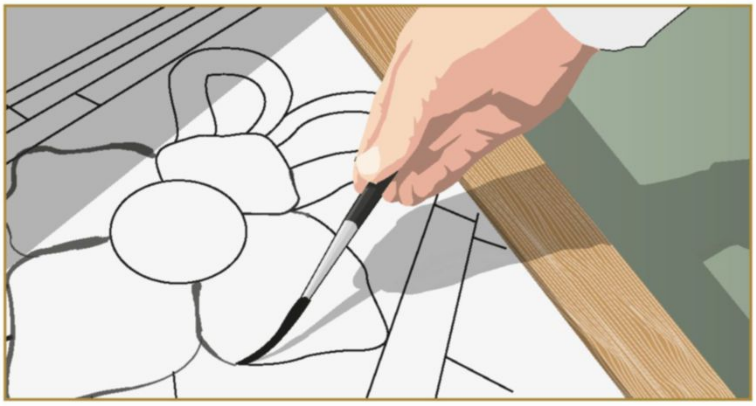
1984
In 1984 the first Sony Discman was released, helping increase the popularity of CDs as an audio storage medium.

1992
MiniDiscs were effectively downsized CDs, but this technology eventually lost out to the MP3 players that were introduced in the late 1990s.

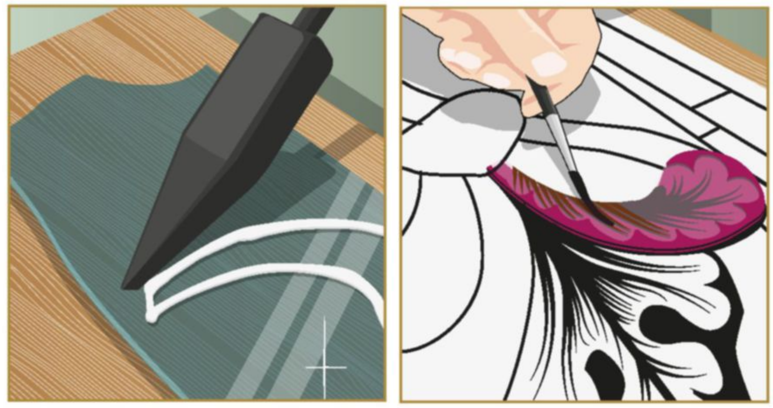
2001
The first-generation iPod was unveiled, offering an unprecedented '1,000 songs in your pocket'.

How to make stained glass

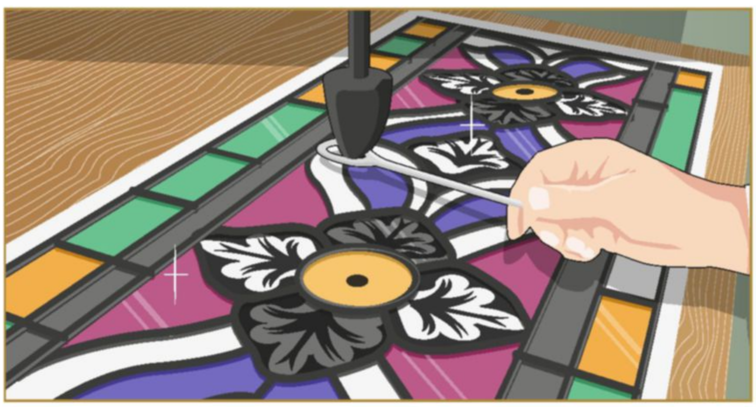
Find out how medieval artists created colourful windows to decorate their churches, cathedrals and other buildings



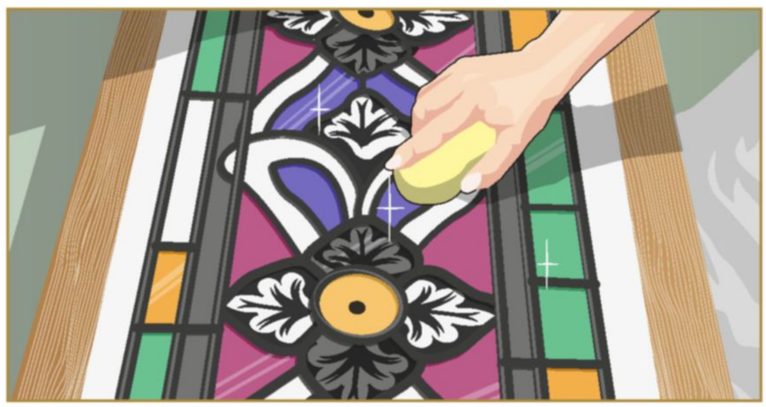
1 Starting sketch
An initial drawing is made first. In a process called cartooning, the design of the entire window as well as the shape and colour of individual pieces of glass are decided upon. Molten glass is created by heating a glass mixture to around 1,600 degrees Celsius. It is then cooled and rolled into thin sheets before being scored, ready to cut.



2 Making the pieces
The glass is cut to size using iron tools and placed onto a pattern drawing as a draft. All sharp edges are ground down until smooth. The pieces can then be decorated using a mixture of metallic oxides and ground glass, and an array of brushes are used to create different textures. The paint is then fixed to the glass in a kiln.



3 Assembling the design
Lead strips called cames are used to help join each of the pieces of glass together, using the cartoon as a guide template. Lead is flexible so can be easily fitted around different shaped pieces. Once every section is in position, the joints between the different cames are soldered together to form one complete panel.



4 Finishing touches
The window is fixed with a semi-liquid cement, thought to be made from crushed chalk and oil, to help make sure the glass pieces stay in position. Chalk or sawdust is also applied to help dry the panel, before the finished window is scrubbed with a brush to remove the excess cement from the glass panes.

Phaeton carriages

Dignified upper-class Georgian rides that could get a little dangerous on the open road

Carriages were the best way to travel in Britain prior to the rail boom of the 1840s. One such design was the phaeton, an open body, four-wheeled doorless carriage typically equipped with one or two seats. The design was popular in France, Britain and the US. It was a lightweight carriage that had springy suspension on both its front and rear axles, which could make for quite precarious journeys for passengers if they were travelling at speed.

The phaeton was owner-driven rather than having a driver, and different types included a mail phaeton used by the postal service and the lighter spider phaeton, which was designed with the gentleman driver in mind. Some were so high that the seats could only be reached by ladder. The elliptical springs used on a phaeton carriage were first invented in England in 1804, and the system was carried over and greatly influenced those used on the first automobiles.

The phaeton was a favourite of various British monarchs, from King George IV to Queen Victoria

BRAIN DUMP

Because enquiring minds need to know...

Want answers?

Send your questions to...

How It Works magazine @HowItWorksmag

jack.griffiths@futurenet.com

MEET THE EXPERTS

Who's answering your questions this month?

Laura Mears

Laura studied biomedical science at King's College London and has a master's from Cambridge. She escaped the lab to pursue a career in science communication and also develops educational video games.

Alexandra Cheung

Having earned degrees from the University of Nottingham and Imperial College London, Alex has worked at many prestigious institutions, including CERN, London's Science Museum and the Institute of Physics.

Tom Lean

Tom is a historian of science at the British Library where he works on oral history projects. He recently published his first book, *Electronic Dreams: How 1980s Britain Learned To Love The Home Computer*.

Sarah Bankes

Sarah is the editor of *Photoshop Creative*, has a degree in English and has been a writer and editor for more than a decade. Fascinated by the world in which we live, she enjoys writing about anything from science and technology to history and nature.

Joanna Stass

Having been a writer and editor for a number of years, **How It Works** alumnus Jo has picked up plenty of fascinating facts. She is particularly interested in natural world wonders, innovations in technology and adorable animals.

Most stars appear white when viewed with the naked eye

Why do stars look the same colour with the naked eye?

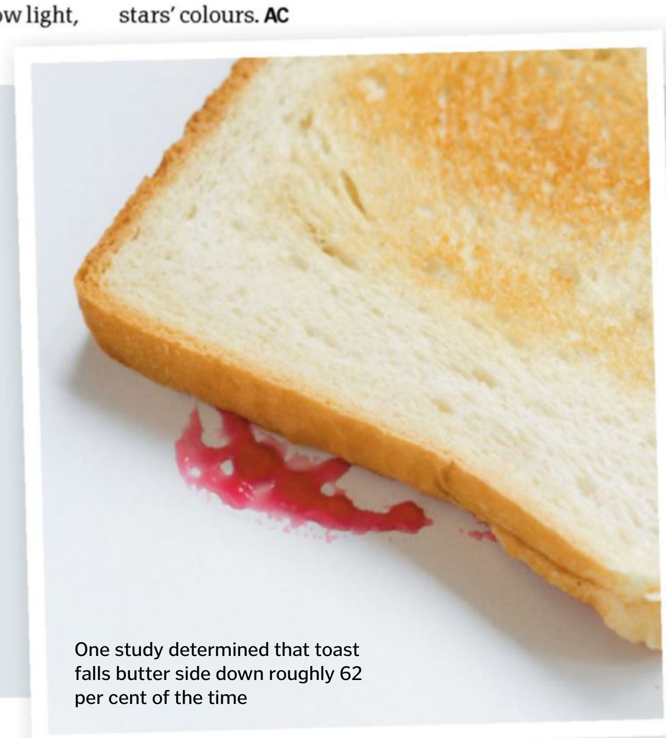
Patricia Rowes

Under dim lighting, our eyes are not sensitive to colour and so we perceive the light from most stars as white, although in reality their colours range from red to blue. Our eyes contain two types of light-sensitive cells – rods and cones. Rods enable us to see differences in brightness, but do not perceive differences in colour. Cones allow us to distinguish colours, but are only effective when light is bright enough. In very low light, we therefore see using just the rods, essentially viewing our surroundings in black and white. Similarly, when gazing at a faint light such as a star in the night sky, we see only white, even if the star is actually red or blue. Under good viewing conditions, the colours of the brightest stars can however be perceived with the naked eye. Binoculars or a telescope focus more light towards your eye, allowing you to see stars' colours. **AC**

Why does toast land butter side down?

Tad Winslow

The height of the average table is such that a tumbling slice of toast typically only has time to make half a rotation before it hits the floor face down. The toast's spin depends on the size of the toast, the height of the fall and the angle at which it is dropped. Since toast usually falls at an angle, it begins to rotate, but is likely to reach the floor midway through its first rotation. To make it more likely to land face up, you could drop it from twice the height, or perhaps eat your toast upside down. **AC**



One study determined that toast falls butter side down roughly 62 per cent of the time

Planes only take off and land from Antarctica during the summer months

How do planes land in Antarctica?

Vanessa Benes

■ Aircraft in Antarctica typically use skis to land on 'skiways' made of compacted snow. However, wheeled planes can also land on ice under the right conditions. Most planes are equipped with interchangeable wheels and skis so that they can take off from solid ground and land on snow. Taking off from skis is particularly tricky, but booster rockets can be used to help pick up speed. Pilots in Antarctica also have to contend with strong winds, snow and sudden changes in weather. In the heart of the Antarctic winter, when 24-hour darkness reigns, treacherous conditions mean flights are operated only in an extreme emergency. **AC**

To pass the Turing test, a computer must carry a conversation like a human

What is the Turing test?

Ellie Reeve

■ The Turing test is an experiment used as a benchmark for artificial intelligence, developed in 1951 by Alan Turing. In a Turing test, the interrogator exchanges written messages with either an artificial intelligence or a person, seeking to establish from their responses whether they are a machine or a human. In one variation of the Turing test, if the computer is taken for a human more than 30 per cent of the time during a series of five- minute conversations, it passes as 'intelligent'. Some claim that the Turing test was passed for the first time in 2014 by a computer programme called Eugene Goostman, which fooled 33 per cent of judges into believing it was human. **AC**

Why don't we go back to the Moon?

Samuel Deeble

■ The last manned mission to the Moon was Apollo 17 in 1972, but various orbiters have continued to probe our closest neighbour ever since. We stopped sending humans mainly due to a lack of funding. Once the Space Race between the US and the Soviet Union was over, the public and political leaders lost interest in space exploration and so funding was scaled back. Priorities within the field also changed, shifting towards building space stations and sending humans into low-Earth orbit instead. Space agencies and some private companies are now setting their sights on a more distant target, with plans to reach Mars by 2030. **JS**

BRAIN DUMP

The chemicals in tablets interact with the digestive system in different ways

Why do some medicines have to be taken with water and others taken with meals?

Riley McClane

■ When you swallow a tablet, the active ingredients in the medication need to enter your bloodstream. Tablets don't spend very long in your mouth, and the stomach lining is coated in thick mucus, so most medicines are only absorbed once they reach the small intestine. This means that they have to survive the first part of your digestive system unharmed. Eating food increases the amount of acid in the stomach and the secretion of digestive enzymes, and some medicines can end up being destroyed if they are taken with a meal. For others, particular foods, like grapefruit, bananas and green vegetables, can interact with the active ingredients and neutralise their effect. Some are absorbed better with food, and for others a meal can help to prevent nausea or damage to the stomach lining. The instructions for different medicines depend on their ingredients, so it's always best to take the advice of your doctor and to read the advice sheet included in the packet. **LM**

Lemurs have been able to survive on Madagascar thanks to the island ecosystem's isolation

Why do lemurs only live on the island of Madagascar?

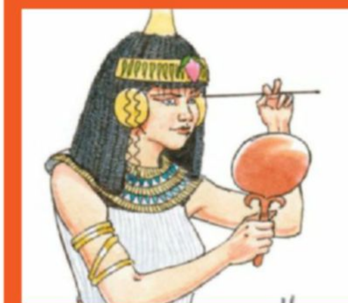
Kelly Evans

■ Around 160 million years ago, Madagascar broke away from Africa. Records of lemur-like primate fossils date back approximately 60 million years have been found in mainland Africa, and further records show that they soon made the journey to Madagascar, which continued to drift east. Roughly 30 million years later, when monkeys made an appearance, they drove lemurs in other parts of the world towards extinction. However, the lemurs on Madagascar were isolated from predators and competition, thriving to this very day in all of Madagascar's ecosystems. They have now evolved to be even more like their intelligent and adaptive primate monkey cousins. **SB**

FASCINATING FACTS

What was Egyptian makeup made of?

Kohl was made from carbon, lead sulphide or manganese oxide. Green makeup was made from malachite and other copper-based minerals, and rouge was made with ground red ochre mixed with water. **SB**



What part of the world is furthest from the centre of the Earth?

Earth's slightly flattened shape means it bulges around the equator, making Mount Chimborazo in Ecuador the furthest point from the planet's centre, although Everest is higher above sea level. **AC**

Why aren't our eyelids completely opaque?

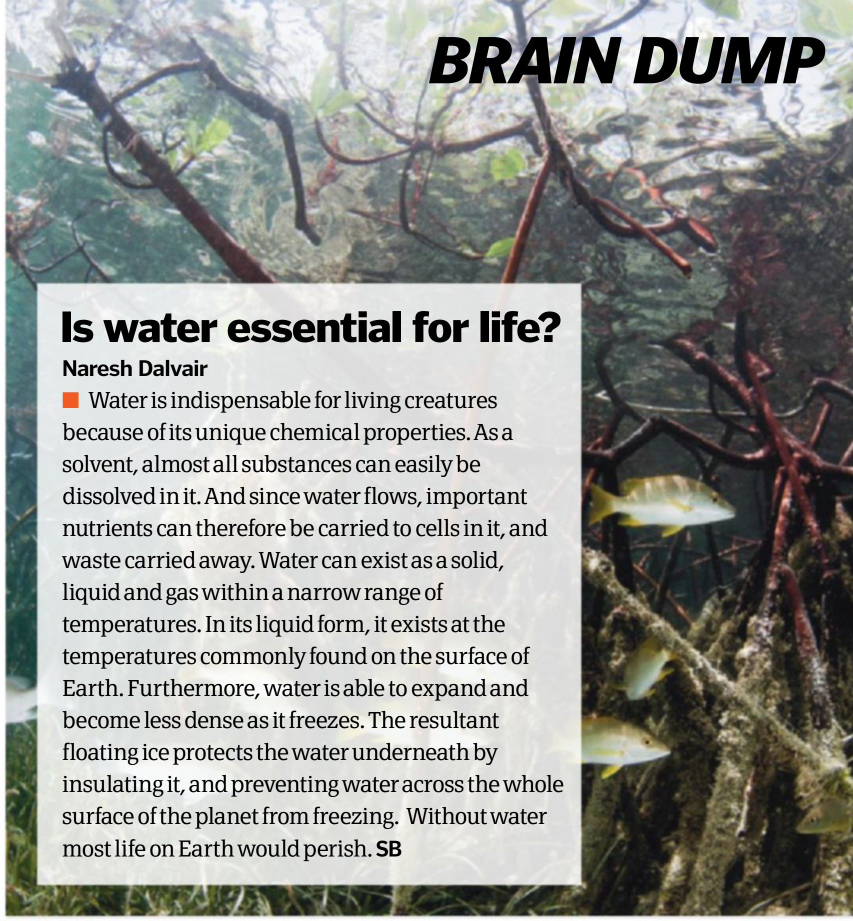
Our cells are mostly transparent, and your eyelids have the thinnest skin anywhere in the body, so light can still get through. It's tinted red because it has to travel through your blood vessels. **LB**

Bone-conducting headphones feature vibrating pads that rest against the sides of your head

How do bone conducting headphones work?

Rich Elliot

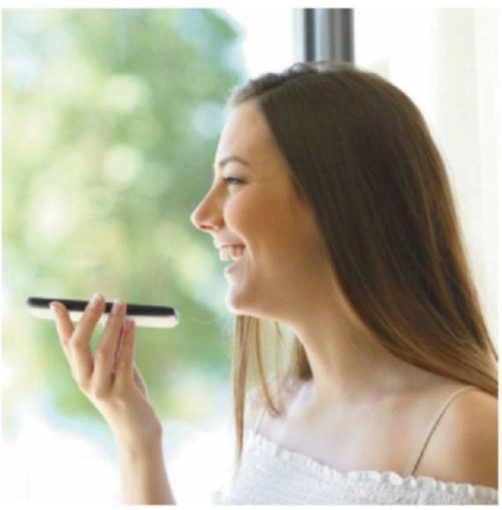
■ When you listen to music through regular headphones, the sound waves travel through your ears and cause your eardrums to vibrate. These vibrations then reach a fluid filled structure called the cochlea in your inner ear, which converts them into electrical impulses and sends them down the auditory nerve to the brain. Bone-conducting headphones bypass the first part of this process altogether, as instead of transmitting sound waves into your ears, they vibrate the bones inside your head. These vibrations then travel directly to the cochlea, protecting your eardrums from the damage that can be caused by listening to loud music, reducing the risk of long-term hearing problems. **JS**



Is water essential for life?

Naresh Dalvair

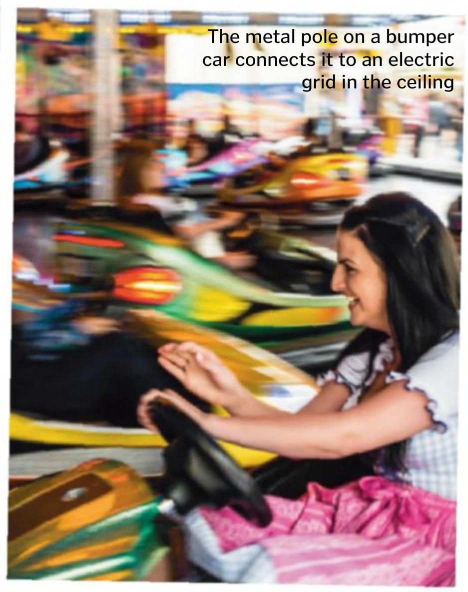
■ Water is indispensable for living creatures because of its unique chemical properties. As a solvent, almost all substances can easily be dissolved in it. And since water flows, important nutrients can therefore be carried to cells in it, and waste carried away. Water can exist as a solid, liquid and gas within a narrow range of temperatures. In its liquid form, it exists at the temperatures commonly found on the surface of Earth. Furthermore, water is able to expand and become less dense as it freezes. The resultant floating ice protects the water underneath by insulating it, and preventing water across the whole surface of the planet from freezing. Without water most life on Earth would perish. **SB**



How does voice recognition work with different accents?

Gabriel Mitchell

■ Voice recognition systems use a number of different techniques, but basically they rely on analysing the sounds we make, breaking them down into a pattern of data, then matching this with a database of sounds that correspond to particular words. The databases were originally collected from people speaking very clearly, but because words spoken in an accent don't properly match with these, voice recognition systems sometimes don't work very well when people talk with accents. However, as these databases have got larger they include more audio samples from people speaking in accents, so voice recognition systems should get better at recognising them with time. **TL**



The metal pole on a bumper car connects it to an electric grid in the ceiling

How do bumper cars work?

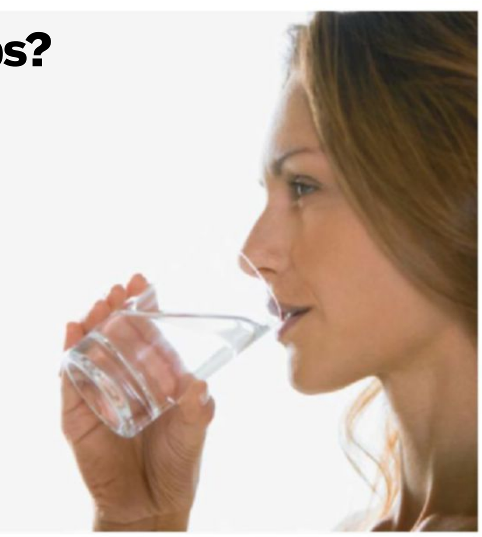
William Anderson

■ Bumper cars are powered by electricity. When you press on the pedal to make the car go, you switch on a motor that drives it forward. Unlike other electric cars, which run on batteries, most bumper cars draw their electricity from the ceiling or the floor. A metal pole on the car reaches up to a grid of electric wires in the ceiling and contacts underneath the car connect it to the metal floor, completing an electric circuit when the ride is switched on. Modern bumper cars sometimes use a different system, drawing their power from electrified metal strips on the floor instead. **TL**

Is there a cure for hiccups?

Gordon Bombay

■ Hiccups are caused by a sheet of muscle under the lungs, called the diaphragm. Its normal function is to draw air in and out of the lungs, but if it contracts suddenly, air rushes in past the vocal cords and they close, making a hiccup sound. These involuntary contractions are thought to be caused by the phrenic nerve, which supplies the diaphragm itself, and the vagus nerve, which commands the heart, lungs and digestive system. Attempts to cure hiccups work by trying to disrupt these signals and get the diaphragm back under control. For example, holding your breath, drinking a pint of water or breathing into a paper bag. **LM**



BRAIN DUMP

Gorbachev (left) won the Nobel Peace Prize in 1990 for helping to end the Cold War

Why did the USSR break up?

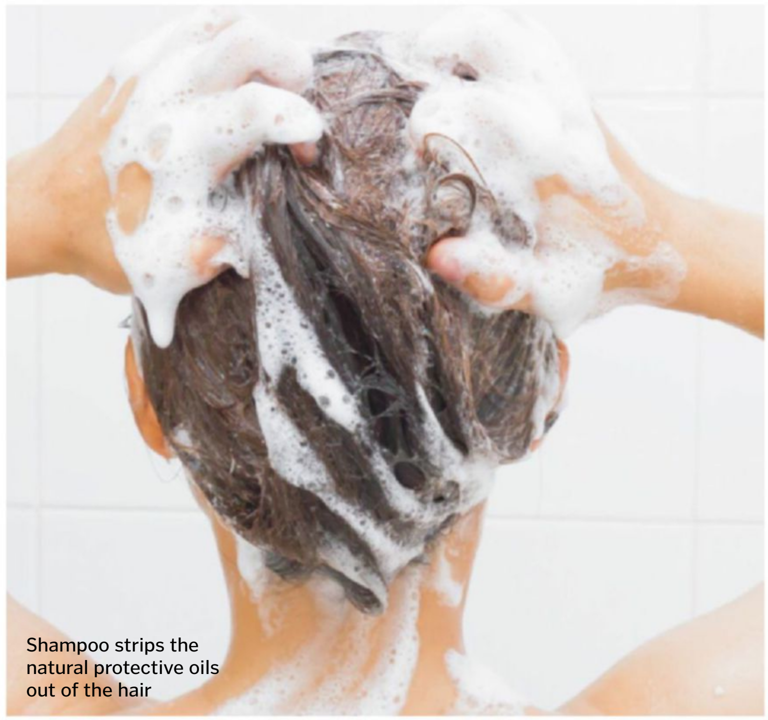
Manuel Gonzalez

■ The dissolution of the Soviet Union was kick-started by the radical reforms implemented by the last Soviet president, Mikhail Gorbachev. The long-time Communist Party politician came to power in 1985, and inherited a stagnant economy, which he addressed with a two-tiered policy of reform. The first tier was the policy of 'glasnost', or freedom of speech, and the second was the policy of 'perestroika', or restructuring, which loosened the government's grip on the economy. However, this second tier was slow to produce results, and so the public used their newly allotted freedom of speech to express their frustration with the government. The governments on the fringes of the USSR began a series of nationalist independence movements and broke away from the power of Moscow one by one. On 25 December 1991, Gorbachev resigned and the Soviet Union soon fell, with the new Commonwealth of Independent Republics forming in its place. **JS**

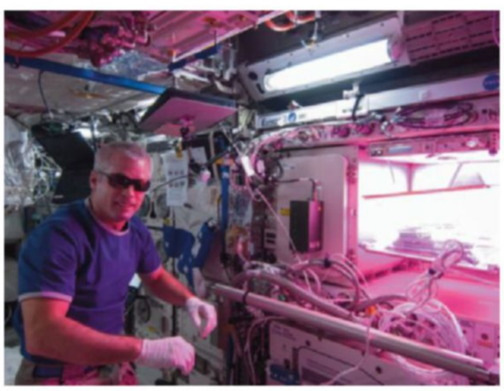
Is hair really self-cleaning?

Lionel Simmons

■ Yes and no. Shampoos get your hair clean through the action of detergents designed to remove oil, sweat, dead skin cells and dirt from the hair and scalp. The body can't do this naturally, but it does have its own cleaning mechanism. The scalp naturally produces a fatty substance called sebum, which helps to protect the skin and stop the growth of microbes. If you stop washing your hair, this oil starts to build up, but after a while it tends to reach a balance; it won't feel as 'clean' as if you washed it with detergent, but it won't keep getting greasier either. **LM**



Shampoo strips the natural protective oils out of the hair

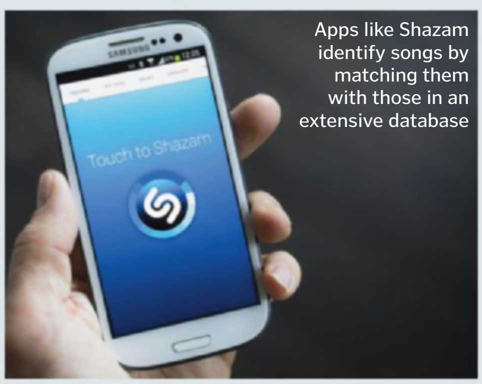


Are the plants grown onboard the ISS safe to eat?

Olivia Ashcroft

■ Plants are grown on the International Space Station (ISS) in a space garden called the Veggie system. Instead of growing in soil under the Sun, the plants grow on 'pillows' of nutrients beneath LED lighting. They are small-scale and mostly experimental, but safe to eat. **TL**

How do music-identifying apps work?



Apps like Shazam identify songs by matching them with those in an extensive database

Lance Ashley

■ Music identifying apps like Shazam are able to tell you the name and artist of a song by listening to a short sample of it through your device's microphone. To do this, the song must have first been 'fingerprinted' by the service and included in its database. This involves plotting the song on a time-frequency graph called a spectrogram, with points of peak intensity of frequency recorded as a fingerprint. When you activate the app it searches the database for a match. **JS**

FASCINATING FACTS

What did the first Space Shuttle mission do?

Cid Jacobs

■ The first four Space Shuttle missions carried out a few experiments, but they were mostly just to test-fly the Shuttle itself. The first operational mission was the fifth, when the Shuttle deployed two satellites. **TL**

We eat peanuts alongside other nuts, and so associate them more as nuts than legumes

Why aren't peanuts real nuts?

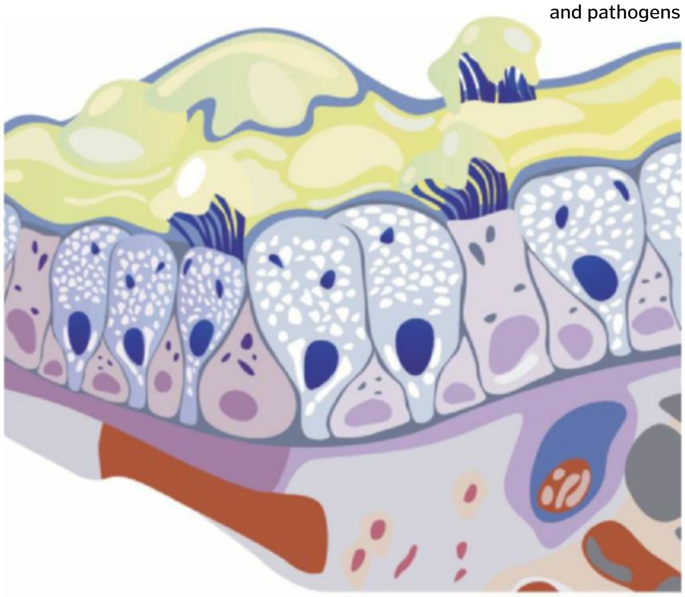
Tilly Hazelroud

■ Despite its name, a peanut is actually a legume, not a nut. True nuts, such as walnuts and almonds, grow on trees. Legumes, on the other hand, are edible seeds that grow underground. A peanut is composed of a seed, known as a kernel, which grows inside a pod and resembles other legumes such as beans and lentils in terms of its structure and nutritional value. However, we don't consume the peanut's pod, like we do with other legumes. Furthermore, the way we include peanuts in our diet far more resembles the way we eat nuts than it does other legumes. **SB**

Why do we produce mucus?

David Sanchez

■ Mucus is a sticky fluid made from proteins coated in sugar molecules. These act a bit like sponges, attracting lots of water to become a thick gel. It is produced by lots of different parts of the body, and in different places it serves different functions. For example, in the airways, mucus helps to trap particles in the air before they reach the tiny air sacs of the lungs, while in the digestive system it helps to lubricate food as it slides down the throat and through the intestines. Mucus also helps to protect the stomach lining from the burning effects of stomach acid. **LM**



Mucus coats the inside of the nose and airways, trapping dirt and pathogens

Why don't trains go uphill very well?

Elliot Smith

■ Trains are very efficient at travelling on level ground because there is so little friction between their metal wheels and the smooth metal tracks. Also, only a tiny part of their wheels are in contact with the rails at any time. When the train goes uphill, however, it has to work harder to overcome the effects of gravity, but as the wheels have so little grip on the rails the train struggles to increase its tractive force and slows down or slips. Mountain railway trains sometimes use a cogwheel to grip a rack on the tracks to help them climb better and prevent slipping. **TL**

Mountain railways sometimes use a racked rail and cogwheel train for better grip

Which monarch had the shortest reign?

Jeremy Small

■ One of the shortest-reigning monarchs was King Louis XIX. Louis-Antoine of France succeeded his father in July 1830, but he abdicated within 20 minutes of ascending the throne. Louis-Antoine shares the record with Crown Prince Luis Filipe of Portugal, who became king once his father was assassinated on 1 February 1908. However, Luis was wounded in the same attack, dying 20 minutes after his father. **SB**

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BOOK REVIEWS

The latest releases for curious minds

100 Steps For Science: Why It Works And How It Happened

Travel through time with this introduction to key scientific discoveries

- Author: **Lisa Jane Gillespie**
- Publisher: **Wide Eyed Editions**
- Price: **£14.99 / $22.99**
- Release date: **Out now**

Complex scientific ideas are tough. There's a reason that major discoveries are so rare – you need to be pretty smart to actually make them! But with books like this, learning about a whole range of scientific topics isn't just easy, it's also good fun.

100 Steps For Science packs in 100 different theories, developments, and technological advancements, and explains them all in a way that is easy to understand. The book is separated into ten topics, including Space, Sound and Medicine. Within each of these you'll find ten theories or developments that fit into the theme. These smaller chunks of information are explained chronologically; the Wheels section starts with the log rollers used during the Paleolithic era, then progresses to water wheels, pulleys and eventually renewable energy produced by wind turbines.

This layout works really well; as you progress through a topic, you start to see how far science has come in each area. These smaller sections are quite concise, however, so each theory or development is really only covered in brief. This book isn't going to teach you or your child everything there is to know about fibre optic communications, for example. However, what it does do is provide an ideal place to start with scientific study. The book explains enough to get a general grasp on the topic and pique your interest. From there, you can choose the topics you are interested in and take your study further.

The book also excels at imagery. It's packed with bright, colourful illustrations by Yukai Du, and they really do help to bring the science to life. For example, the topic of metals may not sound like the most interesting in the book, but thanks to the beautiful illustrations we were drawn straight in.

This is one reason why we don't particularly fault the book for being brief on certain topics. If it got too caught up in explaining alternating current, for example, there would be less colour and less attractive design, detracting from its vibrant look and feel.

There are complex ideas here, but they're explained well thanks to smart writing and wonderful illustrations, and while you won't get a comprehensive guide to every topic, this book is great for young minds craving information.

YOU MAY ALSO LIKE...

Science: Year By Year

Author: **Prof. Robert Winston**
Publisher: **DK**
Price: **£25.00 / $24.99**
Release date: **Out now**

100 Steps has ten smaller timelines, while this book aims to cover all of science in one giant timeline. With small sections on each period and discovery, it's packed with information.

Home Lab

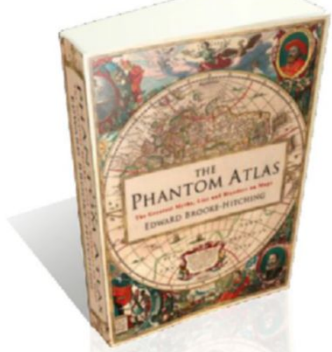
Author: **Prof. Robert Winston**
Publisher: **DK**
Price: **£12.99 (approx. $16)**
Release date: **Out now**

Now that you've learned a little science, why not try it for yourself? Also by Professor Robert Winston, this book is full of great experiments that you can try at home, with scientific explanations alongside each one.

Curiositree: Natural World

Author: **AJ Wood and Mike Jolley**
Publisher: **Wide Eyed Editions**
Price: **£17.99 / $27.99**
Release date: **Out now**

This is another beautifully illustrated book from Wide Eyed Editions. It focuses on the natural world, explaining why life forms evolved the way they did.



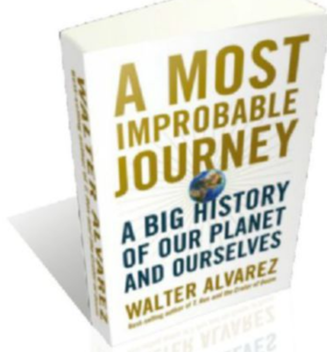
The Phantom Atlas: The Greatest Myths, Lies And Blunders On Maps

The links between myths and maps

- Author: **Edward Brooke-Hitching**
- Publisher: **Simon & Schuster**
- Price: **£25 (approx. $31)**
- Release date: **Out now**

Space exploration has removed much of the sense of mystery surrounding Earth, making books like *The Phantom Atlas* an even more intriguing read. Shorn of certainty regarding the layout of Earth, early cartographers were reduced to educated guesswork, although this book is far more concerned with their outright fantasies.

From Atlantis and the Sea of Monsters to the Island of California and the sunken city of Vineta, these are truly tales to astonish. The maps within are almost worth the price alone; the alternately hilarious and horrifying anecdotes are an added bonus.



A Most Improbable Journey: A Big History Of Our Planet And Ourselves

The science behind the world we live in

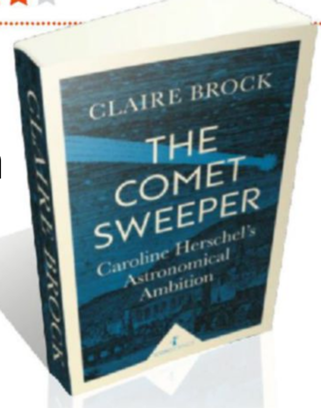
- Author: **Walter Alvarez**
- Publisher: **Norton**
- Price: **£20.00 / $26.95**
- Release date: **Out now**

Generally, the history of our universe has been studied from a historian's standpoint, skipping ahead millennia to examine the human impact on Earth. Here, noted geologist Walter Alvarez takes a different approach, viewing things from a scientific perspective.

Rather than looking at how humans have driven the history of the world, Alvarez takes the reader on a different path, with detailed passages on how the movement of continental landscapes shaped life and how the planet's resources pointed humans in the right direction. It's not an in-depth guide, but it's still a recommended read.

The Comet Sweeper: Caroline Herschel's Astronomical Ambition

The story of the UK's first female professional scientist



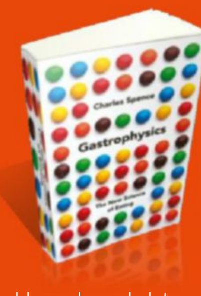
- Author: **Claire Brock**
- Publisher: **Icon**
- Price: **£8.99 / $14.95**
- Release date: **Out now**

The life of Caroline Herschel is a remarkable one. Partially blinded by typhus as a child and later employed in domestic servitude, she overcame her troubled upbringing to become the first woman in the UK to earn a living from scientific research. This fascinating story is told with the help of diary entries and letters from the pen of Herschel herself.

Brock's book is more preoccupied with Herschel the person than Herschel the scientist, and it's definitely an approach that works, with the first person accounts doing much to lay bear Herschel's utter determination to succeed in the face of the numerous obstacles she faced. For inspiration, look no further.

Gastrophysics

A fascinating and revealing insight into the science of eating

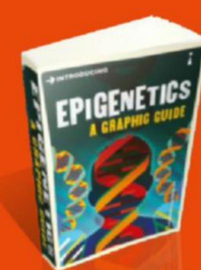


- Author: **Professor Charles Spence**
- Publisher: **Viking**
- Price: **£16.99 / (approx. $21)**
- Release date: **Out now**

Enjoying good food isn't just down to its taste and flavour. The look, smell, touch and even the sound of a dish can make or break a meal. Written by Oxford professor Charles Spence, *Gastrophysics* reveals a lot you probably didn't know about your food. For example, did you know that eating food from a blue coloured plate makes it taste saltier? Interesting facts like this are littered throughout this book, which could well change how you eat your meals. From how restaurant menus encourage diners to order a particular dish to the future of food, you're sure to learn a lot.

Introducing Epigenetics: A Graphic Guide

How do genes make us who we are?

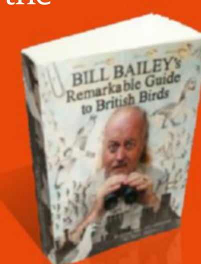


- Author: **Cath Ennis**
- Publisher: **Icon Books**
- Price: **£7.99 / $9.95**
- Release date: **Out now**

Your DNA provides the blueprint for your body, but this information can be expressed differently. The study of epigenetics concerns how genes can effectively be switched on and off, how this affects our development, and how our environment can influence these changes. *Introducing Epigenetics: A Graphic Guide* explains the basics of this fascinating field and its potential applications, and its many illustrations help to visualise some of the more complex ideas. That said, in a title marketed as a 'graphic guide' we were expecting a little more colour and explanatory infographics.

Bill Bailey's Remarkable Guide To British Birds

A fun scrapbook written by the popular British comedian



- Author: **Bill Bailey**
- Publisher: **Quercus**
- Price: **£20 / $28.99**
- Release date: **Out now**

This funny and informative book appeals to bird-watchers and Bill Bailey fans alike. Bailey enjoys bird-watching in his spare time, but right throughout this title you will find reminders of his day job, with quirky and surreal sketches and notes about some of the UK's birds. This scrapbook-style book is a fun guide that showcases a huge range of birds, from the bar-tailed godwit to the red-throated diver. This could easily be a book just for bird-watchers, but Bailey succeeds in making it a rewarding read for all, thanks to his humour and infectious enthusiasm.

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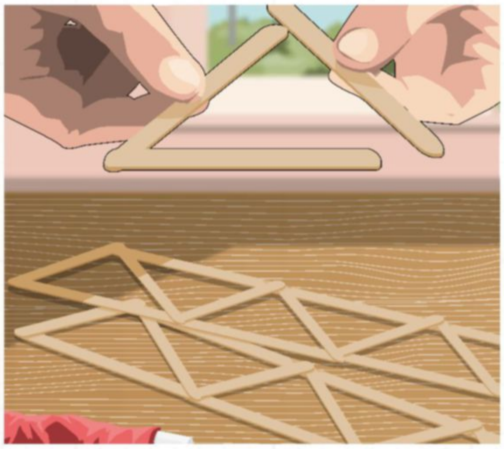
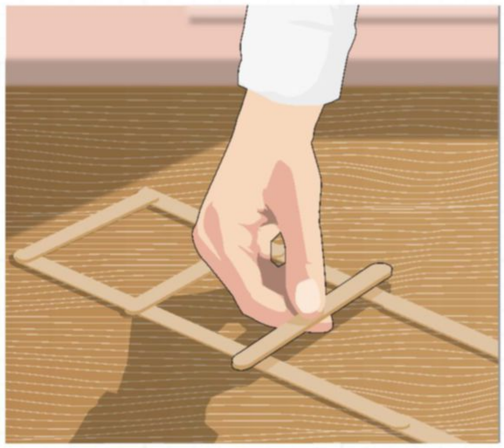
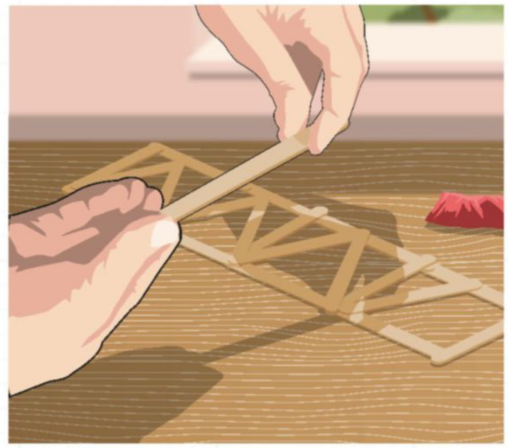
DON'T DO IT ALONE
IF YOU'RE UNDER 18, MAKE SURE YOU HAVE AN ADULT WITH YOU

Build a sturdy bridge

Make a bridge that can take the weight of a few bricks... with lolly sticks!







1 Make the sides

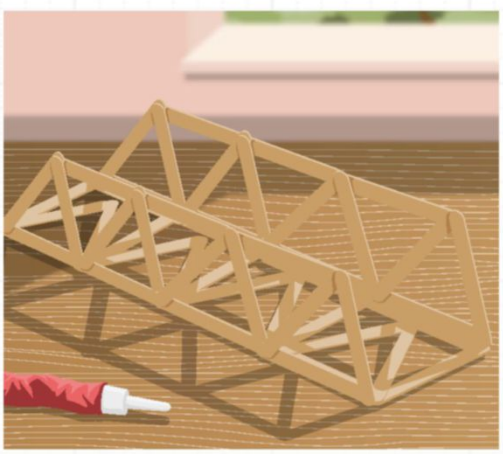
Start by making the sides of your bridge. Take three lolly sticks and stick them together in the shape of an equilateral triangle. Attach them with plenty of glue to make sure they're strong. Now attach another stick to the first, then add more sticks to make several triangles in a row, with more sticks at the top to strengthen them. Repeat the process for the other side.

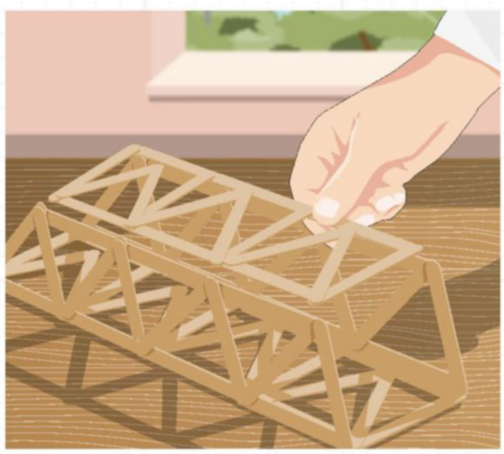
2 Create the base

For the base, stick several lolly sticks together in a line, then make another the same length. Use glue to attach more sticks across the two longer lines at right angles. Your base should look like a row of around four squares, and this should be the same length as your row of triangles. That's the main sections of your bridge finished, but before putting it together, we need to reinforce it.

3 Make it stronger

We're now going to add two more sticks inside each square. Use a dab of glue on the ends of each stick, but be sparing as you don't need to use too much. You should now have a base that looks like two long lines with a zigzag line running down the centre. You'll need to repeat this process again for the top of the bridge, but that will be slightly shorter.





4 Attach the sides

This step can be a little bit awkward, but it's important. Hold one side of the bridge at a right-angle to the base, and using masking tape, attach the base to the side. You'll need to wrap the tape tightly around the two pieces to secure it. An extra pair of hands helps here, so ask a grown-up or a friend to help. Then do the same with the second side.

5 Top it off

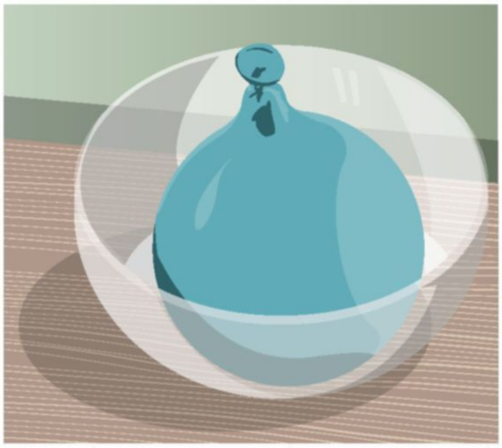
You can now attach the top of your bridge with tape, just as you did with the base. Wait as long as you can to make sure the glue is set before you test it. Carefully put something heavy, like a brick, on the top of the bridge. It should support the weight – if it slips sideways, try adding more lolly sticks inside the bridge structure to make it even stronger.

"Your bridge should be able to support the weight of a brick"

In summary...
Adding sticks at angles and attaching them strongly with glue helps to spread the weight placed on top of the bridge between all the sticks at the same time. If the sticks weren't attached, the structure would collapse. When the weight is added, some sticks are compressed while others are under tension, helping the bridge to withstand the pressure.

How to create icy orbs

Make incredible patterns in ice with food colouring and some salt



1 Create your orb

First, you need to make an orb of ice. Take a balloon and place the opening over the end of a tap. Turn on the tap so water trickles out slowly and half-fill the balloon with water. When it's almost full, tie the balloon, place it in a bowl, and put the whole thing in the freezer overnight. Leave the tied section pointing upwards when you freeze it. This will create a small, flatter area on top of the orb, which will be useful later.

2 Add some salt

When your orb has frozen, use a pair of scissors to cut the tied end of the balloon off. Then, peel off the rest of the balloon – the ice should have solidified so this shouldn't be too difficult. Place the ball of ice back in the bowl and sprinkle a little salt on the top of the orb. The salt will mix with the melting ice and lower its freezing temperature, ensuring that the exposed part of the orb remains in a liquid state.

3 Create a pattern

Now you can dribble a few drops of food colouring onto the ice. Where the ions in the salt have retained the ice as water, the colouring will dissolve in the water droplets and drip down the orb, creating amazing patterns on the outside of your ice ball. You can add different food colourings as well to create an even more impressive effect. For a spectacular light show, shine a torch up through the bottom of the orb!

"To make a light show, shine a torch through your orb"

In summary...

The ions in the salt crystals help to retain water in its liquid state by lowering its freezing temperature. This is useful in the winter, when special lorries spread salt on roads and pavements to help melt ice that is already on those surfaces and stop more ice from forming.

WIN!

A Kito+ health tracker worth £99!

The Kito+ tracker can be used to monitor your heart rate, blood oxygen levels, skin temperature, respiration rate and can take an electrocardiogram to track your heart's electrical activity. What's more, the Kito+ doubles up as a phone cover, compatible with Android smartphones and 6th generation iPhones.

Dual-purpose
The Kito+ is a health monitor and phone case combined.

Sensors
Health checks are quick and easy. Just hold your fingers over the sensors for a few seconds and the accompanying app will show your stats.

Which Bugatti model features in this month's supercar article?

a) **Chiffon**
b) **Croissant**
c) **Chiron**

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HOW SUPER COOL STUFF WORKS
Filled with incredible images and astounding gadgets, this book is your guide to current and future tech, from supercomputers to underwater hotels.

Letter of the Month
The science of pruney fingers

Dear **HIW**,
I was wondering, why is it only our fingers, hands, toes and feet that go wrinkly after being in contact with water? I know why it happens, because the waterproof oil on our skin washes off, making it go wrinkly, but why is it only our fingers, toes, hands and feet that are affected?
Charlie Gask

Great question Charlie! One theory is that wrinkly fingers and toes – which are an involuntary reaction caused by blood vessels constricting – help our hands and feet maintain grip in wet conditions, similar to how tyre treads help grip wet roads. Macaques also get wrinkled fingers and toes after exposure to water, and it's thought that other primates do too, although no scientists have thought to check the other apes and monkeys yet! It's thought that 'prune fingers' is an evolutionary trait that helped our ancestors gather food from rivers and streams, with the wrinkles channelling away water from our hands and feet so we can grasp and grip in wet conditions.
One study found that volunteers could pick up objects like marbles in wet conditions more easily if their hands were wrinkly compared to normal. However, a later study, with a greater number of participants performing the same object-picking exercise, did not find a significant difference between wrinkled and non-wrinkled task completion times. It seems a few more experiments are needed!


It is still not known exactly why we get 'prune fingers', but one theory is that it gives us better grip on wet surfaces

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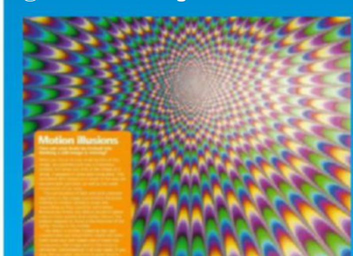
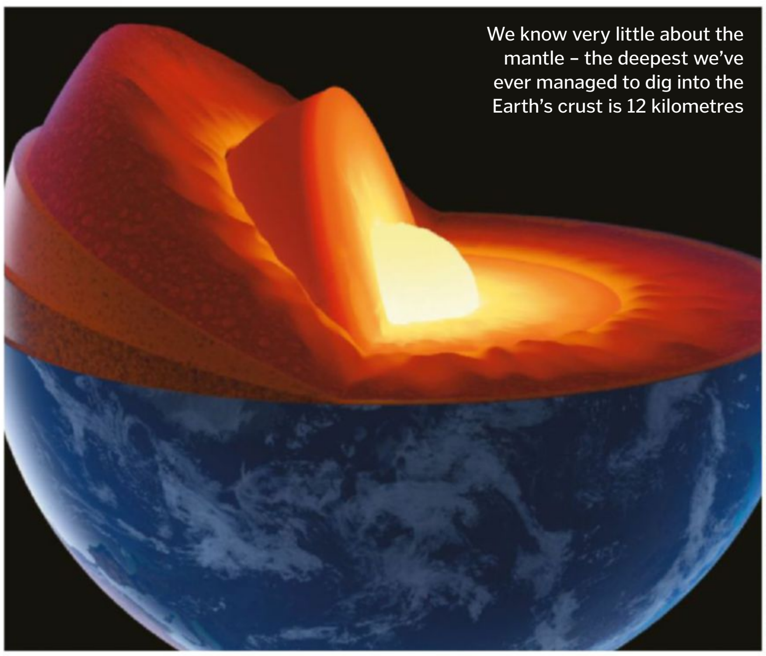
3.14 Happy Pi-day to Gregorian calendar users who reckon dates with month followed by day separated by period, omitting year

@amitsingh8888
Yes, I am feeling very foolish now!" @HowItWorksmag




We know very little about the mantle – the deepest we've ever managed to dig into the Earth's crust is 12 kilometres

Journey to the centre of the Earth

Dear **HIW**,
What would happen if a hole was drilled directly into the Earth's mantle, in a similar turn of events to what happened in the *Doctor Who* episode *Inferno*? Would it end in the destruction of planet Earth?
Madeline Grieveson

Strangely enough, the US and the USSR tried to do exactly this during the Cold War. The US's Project Mohole only reached 183 metres below sea level before they ran out of funds, but the USSR's Kola Superdeep Borehole reached a depth of 12 kilometres before the surrounding temperatures jumped from 100 to 180 degrees Celsius, causing the drill to malfunction. Even with modern drilling equipment, temperature and pressure are the main obstacles for drilling deep into the crust and mantle. If we did ever develop the technology to do so, though, it wouldn't result in the destruction of the Earth. If we did dig down into it, molten mantle rock wouldn't just burst out, as it only travels at a very slow pace. If we did ever access the mantle it would be a huge breakthrough for science. We would greatly increase our knowledge of our planet's history by being able to obtain geological samples that have never been excavated before.

Radiation shields

Dear **HIW**,
What protects the astronauts from radiation while they are inside the space station?
Olivia Ashcroft age 7

Radiation from cosmic rays are a major safety concern in human space exploration. Luckily they aren't too much of a problem for the low-Earth orbit ISS, as much of the radiation from space is deflected by the Earth's magnetosphere. Regions of the ISS have been fitted with polyethylene, which has a high hydrogen content. This material provides effective shielding because hydrogen atoms are good at absorbing and dispersing radiation. Hydrogen-based substances could be the key to protecting astronauts in future missions to Mars.


Instruments onboard the ISS constantly measure radiation levels to ensure the astronauts are not at risk of dangerously high doses

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ELECTRONS CAN MOVE THROUGH GRAPHENE AT SPEEDS OF 1 MILLION M/S

600 METRES
THE TOTAL LENGTH OF THE WORLD'S SHORTEST RAIL NETWORK IN VATICAN CITY

3 METRES
THE MAXIMUM DISTANCE A SKUNK CAN PROJECT ITS POTENT SPRAY

10%
AMOUNT OF THE EARTH'S LANDMASS THAT IS COVERED IN GLACIAL ICE

2,000-4,600
THE NUMBER OF STARS VISIBLE TO THE NAKED EYE ON A CLEAR NIGHT

60,000
LITRES OF AIR PUMPED THROUGH THE BUGATTI CHIRON'S ENGINE EVERY MINUTE

$58 MILLION
THE ANNUAL COST TO MAINTAIN NEW YORK CITY'S CENTRAL PARK

27% OF DRINKS BOUGHT ON AIRPLANES ARE TOMATO JUICE

10.39M
THE HEIGHT OF THE WORLD'S TALLEST EASTER EGG

8 MILLION
THE NUMBER OF LINES OF CODE IN THE SOFTWARE OF A F-35 LIGHTNING II

30
MINUTES OF SLEEP SOME WILD GIRAFFES HAVE PER DAY

THE US NAVY'S NEW GERALD R FORD AIRCRAFT CARRIER WEIGHS AS MUCH AS 400 STATUES OF LIBERTY

80
APPROXIMATE PERCENTAGE OF US HOUSEHOLDS THAT OWN A VIDEO GAME CONSOLE

4 BILLION
YEARS FROM NOW THE ANDROMEDA AND MILKY WAY GALAXIES WILL COLLIDE